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Mining and Metallurgical Section.

Stated Meeting, December 28, 1898.

FELDSPARS AND KAOLINS OF SOUTHEASTERN PENNSYLVANIA.*

BY T. C. HOPKINS,
Member of the Institute.

FELDSPARS.

Feldspar, or spar, as it is commonly called by the quarryman, is a class or group name that includes several different mineral species, which have certain general resemblances sufficient to distinguish them from other minerals, and differ among themselves sufficiently to have different names. They all have cleavages in two similar directions inclined

*Based on field-work done by the writer during the summer of 1898, under the auspices of the School of Mines of The Pennsylvania State College, and is here given in advance of the College report with the consent of the President of the College.

to each other at an angle of 90 or nearly so. They crystallize in two systems, the crystals resembling each other in angle, habit, and methods of twinning. They vary in hardness from 6 to 6·5, in fusibility from 3 to 5, in specific gravity from 2·5 to 2·9. They vary in color from white to yellow, red, green, or dark.

The feldspars are for convenience divided into two classes:

(1) Orthoclase, the potash or acid feldspar, and

(2) Plagioclase, the soda-lime or basic feldspars.

All the feldspars are compound silicates of alumina and an alkali base. The silicate of alumina is common to all the varieties, the alkaline base consisting of potash, soda or lime, rarely baryta, varies in the different species. The first group is called acid because it has a high percentage of silicic acid. It is called orthoclase (meaning straight cleavage) because of the straight cleavage of two faces at right angles to each other.

Chemically, orthoclase is potash alumina silicate, $KAlSi_3O_8$ (K_2O, $Al_2O_3 6SiO_2$) consisting of silica (SiO_2) 64·7 per cent., alumina (Al_2O_3) 18·4, potash (K_2O) 16·9. Sometimes soda replaces part of the potash forming soda orthoclase, sometimes, in fact, the soda may be in excess when it forms anorthoclase, a triclinic form in which usually the soda is in proportion to the potash as 2 to 1 or 3 to 1.

Orthoclase differs from the other feldspars crystallographically in that it crystallizes in the monoclinic system while the others are triclinic. The crystal habit of orthoclase is generally prismatic or tabular, commonly with two well-developed cleavages. Twinning of the crystals is quite common and follows one of three laws known as the Carlsbad, the Baveno, and the Mannebacher, the distinctions of which are interesting to the mineralogist, but not to the tradesman.

The plagioclase feldspars differ from the orthoclase in being triclinic and in having, besides a twinning according to one of the above laws, another twinning in accordance with the albite or pericline laws. In both of the latter the twinning is usually polysynthetic, that is, repeated many

times, which causes a striation on either the basal pinacoid (the albite law) or the brachypinacoid (the pericline law). These striations may frequently be seen by the naked eye, but are best observed in the microscope. The microcline feldspar, which is chemically a potash feldspar, is crystallographically triclinic, and usually has both the albite and pericline polysynthetic twinning, thus giving a double striation on a basal section, producing the peculiar "window-grated" texture so characteristic of microcline.

The plagioclase group proper, or the soda-lime feldspars, include a series ranging from the soda feldspar, albite $NaAlSi_3O_8$, at one end to the lime feldspar, anorthite $CaAl_2Si_2O_8$, at the other. There is a more or less intimate gradation of the one into the other, but four other varieties are introduced between these two by drawing arbitrary lines at regular intervals. This makes the classification more detailed, but more complex and less definite. It would be necessary to draw one arbitrary line to separate albite and anorthite, but by introducing the four intermediate varieties there are four arbitrary lines to be drawn. The intermediate forms are oligoclase, andesine, labradorite and bytownite.

With this chemical change noted in passing through the series, there are corresponding crystallographic and optical changes which are interesting to the professional mineralogist, but have no special interest or value to the tradesman.

The point of difference which interests the manufacturer is the change in fusibility which is governed largely by its chemical composition.

The chemical and physical relations of these forms are best shown by tabulating them:

PHYSICAL AND CHEMICAL PROPERTIES OF THE FELDSPARS.

Name.	Ratio of albite 1 to anorthite e. i : n.	Hardness.	Fusibility.	Specific gravity.	Silica.	Alumina.	Lime.	Soda.	Potash.
Orthoclase.	—	6	5	2·57	64·7	18·4	—	—	16·9
Albite.	1 : 0	6-6·5	4	2·624	68·7	19·5	—	11·8	—
Oligoclase.	12 : 1	—	—	—	—	—	—	—	—
	8 : 1	6-7	3·5	2·64	65·7	21·5	2·4	10·4	—
	6 : 1	—	—	—	—	—	—	—	—
Andesine.	3 : 2	—	—	—	—	—	—	—	—
	4 : 3	5·6	—	2·69	57·4	27·1	8·9	6·6	—
	1 : 1	—	—	—	—	—	—	—	—
Labradorite.	3 : 4	—	—	—	—	—	—	—	—
	2 : 3	5·6	3	2·71	53·00	30	12·3	4	—
	1 : 3	—	—	—	—	—	—	—	—
Bytownite.	1 : 4	—	—	—	—	—	—	—	—
	1 : 6	—	—	2·74	46·6	34·4	17·4	1·6	—
	1 : 8	—	—	—	—	—	—	—	—
Anorthite.	0 : 1	6-6·5	3	2·76	43·2	36·7	20·1	—	—

The greater part of the feldspar that goes into the market is orthoclase, and one might expect it would have a uniform composition, but as shown from the following analyses of commercial spars the variation in composition is considerable, which is easily understood when we remember that orthoclase always has a variable percentage of soda and is accompanied by variable quantities of the soda-lime or plagioclase feldspars, and contains considerable but varying proportions of quartz and small quantities of other minerals, such as mica, hornblende, etc. The bulk of the foreign minerals is separated in the quarrying process, as far as possible, by careful hand-picking, but it is not practical to remove all. Moreover, as feldspar yields readily to the weathering agencies, there may be a considerable variation in the composition of the commercial product from different localities or from different parts of the same deposit, dependent on the degree to which this disintegration or kaolinization has taken place.

ANALYSES OF FELDSPARS.

NAME.	LOCALITY.	SiO_2.	Al_2O_3.	CaO.	Na_2O.	K_2O.
Orthoclase (?)	Embreeville, Pa. . . .	67·46	21·76	1·67	5·56	4·28
Orthoclase	Bolton, Mass.	65·23	19·26	·42	2·98	11·80
Orthoclase	Brandywine Summit .	65·61	16·92	·16	2·11	13·92
Albite	Unionville, Pa.	66·65	20·79	1·47	8·86	1·36
Albite	Mineral Hill, Pa. . . .	66·24	20·72	1·85	9·44	0·98
Oligoclase	Wilmington, Del. . .	64·73	23·56	2·84	9·04	1·11
Oligoclase	Sanford, Me.	56·65	25·56	8·25	6·18	1·34
Labradorite	Labrador	56·00	27·50	10·10	5·00	0·40
Anorthite	Mt. Somma	43·98	35·30	18·98	·47	·40

Mode of occurrence.—Feldspar occurs as one of the constituents in a great many different rocks, in fact, in most of the granular igneous rocks and many of the metamorphic ones, in all of which it is associated more or less intimately with a variety of other minerals. While it is one of the most abundant and widely distributed minerals, the localities where it is segregated free from other minerals are comparatively few. The feldspar segregations where it occurs sufficiently pure for commercial purposes in Pennsylvania are in the form of pegmatite veins, or dikes, varying greatly in width and extent. The veins, or dikes,* are frequent in the gneiss and mica schist rocks of Delaware and Chester Counties. They are not limited to the micaceous rocks, however, as some large veins occur in serpentine rocks. The veins may vary in width from an inch or less to 50 feet or more. The actual length is difficult to determine, but, like most veins, they swell out quite large in places, between which enlargements they may be so much restricted as to either partially or wholly cut off the vein. As a result, the commercial spar is obtained from irregular, elongated, lenticular-like masses or pockets, sometimes close to each other, sometimes widely separated by an area of barren rock. As there may be a series of parallel veins, these pockets may lie side by side as well as end to end. In some

*To avoid repetition, I shall hereafter use the word veins, and those who think they are dikes may supply the words "or dikes."

cases there are sharply defined walls to the feldspar deposits, in other cases there appears to be a rough gradation from the spar to the country rock, with no sharp line of separation.

These segregations of feldspar are commonly known as pegmatites, "giant granite" or granitic veinstone.

Pegmatite, as first used by Haüy, in 1822, was synonymous with "graphic granite," that unique intergrowth of quartz and feldspar. In 1843 its use was extended by Delesse to include all the very coarse granites, and is so used to-day. It includes not only the coarse segregations of the granitic rocks, but corresponding types of other plutonic rocks as well, thus we have the syenite-pegmatite, gabbro-pegmatite, etc.

Besides feldspar, the other economic products obtained from the pegmatite veins are mica, quartz and a number of minerals containing the rarer earths. They are also the source of many fine crystals of a great variety of minerals that have no particular economic usage, as the conditions favoring the formation of the great feldspar crystals also favor the crystallization of other minerals.

In the feldspar districts these veins are always referred to as the feldspar or spar veins, but the feldspar is only one of the minerals. In most of the Pennsylvania spar quarries the other minerals that occur in large quantities are quartz, muscovite and biotite, the constituents of ordinary granite. The essential difference between the pegmatite and the ordinary granite is in the greater size of the crystals, but there is commonly a segregation of minerals as well, so that some portions of the vein will be nearly pure spar, other portions nearly all quartz, and other portions very rich in mica.

The great size of some of these separate crystals is truly surprising. Professor Crosby mentions * the frequent occurrence of feldspar crystals in the New Hampshire quarries 10 feet or more in length, and one fully 20 feet long; and Brögger † mentions some 33 feet long.

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* "American Geologist," Vol. 19, p. 154.

† "Canadian Record of Science," 6, 57.

No such giants as these were observed by the writer in the Pennsylvania quarries, but those a foot or more in length are not infrequent.

*The Origin of Pegmatite.**—Much has been written on the origin of pegmatites, and consequently much that is more or less conflicting. The different theories might be grouped in three classes: (1) Those that suppose a purely aqueous origin; (2) A purely igneous one; (3) That they have an aqueo-igneous origin. All of these theories have had able advocates, and possibly there is an element of truth in each. It is possible, indeed it appears quite probable, that all the pegmatite veins have not originated in the same manner.

The first theory allies pegmatite veins with quartz veins, and explains their formation by water carrying the material in solution and depositing it in fissures or along certain planes. Some writers, particularly some of the earlier writers, assumed that the solutions were heated and came from great depths; others, particularly in recent times, advocate the lateral secretion theory, in which the materials are carried in solution to the veins from the surrounding country rock by waters of comparatively low temperature.

The advocates of the second theory argue that the pegmatites are injected igneous material. Professor Williams offers several strong points in evidence of at least some of the Maryland pegmatites being of igneous origin.

The third theory recognizes the solvent power of water and the active agency of heat and combines the two. It is a well-known fact that, in the presence of water, all the rock materials can be rendered plastic or pasty at a much lower temperature than by simple dry fusion, and, therefore, the rock material saturated with water is reduced to a semi-fluid condition at a moderately low temperature, in which the coarsely crystallized pegmatitic material is segregated.

A very little analysis will show that the last theory is

* This subject is ably discussed by Prof. G. H. Williams in the "Fifteenth An. Report U. S. Geol. Survey," 1893-4, pp. 675-684, and by Prof. W. O. Crosby and M. L. Fuller in the "American Geol.," Vol. 19, page 148, 1897. Both articles are illustrated. The first treats more specifically of the pegmatites of Maryland and the second of those of New Hampshire.

simply a connecting link between the other two. The line between aqueous solution and aqueo-igneous solution is an arbitrary one, as is that between aqueo-igneous fusion and pure igneous fusion. Recent investigation appears to rather emphasize the aqueous end more than the igneous. The speaker favors the aqueo-igneous theory, believing that the water is a more important agent than the heat in the formation of the Pennsylvania pegmatites.

An extended discussion of these theories is not justified here, and those interested in pursuing the subject further are referred to the two papers mentioned above, where numerous references are given to other writers.

Method of Quarrying.—The spar is frequently partially disintegrated by the weathering agencies near the surface, where it can be readily removed with a pick and shovel. In many of the deposits these are the only tools used, as the weathering agencies have penetrated with sufficient power to open the cleavage planes and loosen the whole mass, so that it yields readily to the pick. In some places it is so far disintegrated that much of the feldspar is changed to kaolin and near the surface mixed with constituents of the surrounding rock. In such cases it is necessary to cleanse the solid fragments of feldspar from the dirt in which they occur. Where the material is dry this is sometimes done by screening it on a wire netting, such as is used for screening sand. Where the material is not dry enough to screen, it is washed with a stream of water. From the deeper parts of the quarry, where the surface impurities do not occur, neither washing nor screening is necessary. But in all parts of the deposit there is an admixture of other minerals, such as mica, hornblende, quartz, etc., which are broken out and separated by a careful sorting by hand from the quarried material. Where the spar is too hard to yield readily to the pick, powder is used to blast it loose.

Sometimes the quarry is extended downward with nearly vertical walls and the material lifted in buckets with the aid of a derrick, operated in some places by hand-power, in some places by horse-power, and sometimes by steam-power.

In some of the quarries one end of the quarry is carried down on an incline and the spar hauled out with a horse and cart. In two of the Pennsylvania quarries drifts were run in and the spar mined underground. In the one case the drift runs horizontally from the surface on a steep hillside. In the other case the drift was from the bottom of a deep pit, and it was necessary to elevate the material to the surface after it was brought from the drift. After the hand-sorting the broken spar is sent to the spar mill.

There are two spar mills in Pennsylvania, one at Toughkennamon, and a much larger one near Brandywine Summit. Some of the spar is shipped in lump to the mills at Trenton and East Liverpool, where it is ground.

The grinding is a two-fold process, the first part consisting in crushing the material to powder under heavy circular stones or rolls, two of which are mounted on a short horizontal axis, which is attached to a rotating vertical axis. The heavy stone rolls, turning on both the horizontal and vertical axes, run in a pan into which the spar is shovelled by a workman. The process is similar to the ordinary dry pan, except that the rolls are stone instead of iron, and the pan is smaller than the average dry pan. After being thoroughly crushed under these rolls, the material is put in a large iron drum or cylinder along with a mass of flint ("Norway") pebbles and revolved at a rapid rate for two or three hours, which reduces it to an impalpable dust, when it is ready for the potters' use.

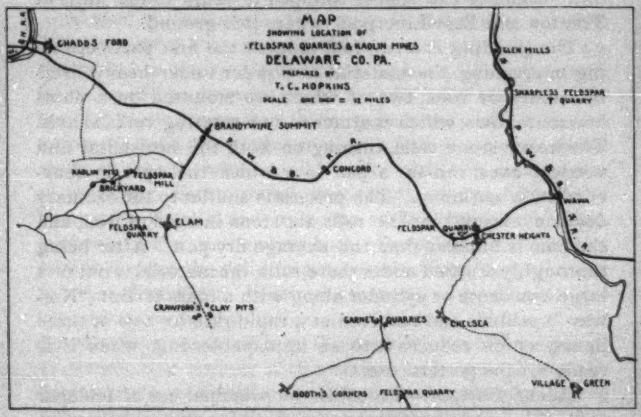
Uses of Feldspar.—Probably the principal use of feldspar is in china and porcelain ware, where it serves the purpose of a flux. It is used both in the body of the ware and in the glaze. It is used to some extent in making glass. It is also used in making enamelled or porcelain brick and enamelled tiling, where it serves the same purpose as in ordinary china ware. Small quantities are used by the dentists for making artificial teeth.

Distribution of Feldspar.—As the spar veins are limited to the gneissoid, schistose and serpentine rocks, the possible productive areas in this State are not large. All the feldspar quarries in Pennsylvania, so far as known to the

speaker, are in southern Delaware and Chester Counties. In 1898 there were ten companies operating seventeen quarries, and there are three other quarries that have been operated within the last few years.

The product of these quarries varies from one to ten tons of spar per day each, and it takes from two to ten men to operate each one.

In Delaware County there are feldspar quarries at Elam Post-office, Chester Heights and near Chelsea. In Chester County there are quarries at Avondale, Chatham, Unionville, Embreeville, Sylmar, Chadd's Ford and Fairville.



At Chester Heights the spar has been quarried from six different openings, and occurs as pegmatite vein deposits in micaceous rocks, the veins having a general northeast-southwest trend, varying in width from 8 to 20 feet, and standing nearly vertical. The quarries are 20 to 50 feet deep, except the last one opened (September, 1898), which is an underground working, and has been started on the vein near the base of the hill by running a horizontal drift into the hill following the vein. Some of the spar consists of graphic granite, some is nearly free from quartz, and from

one opening quartz was removed in large boulders; in fact, the dump has more the appearance of a flint quarry than a spar quarry. The spar is all shipped to the mill near Brandywine Summit.

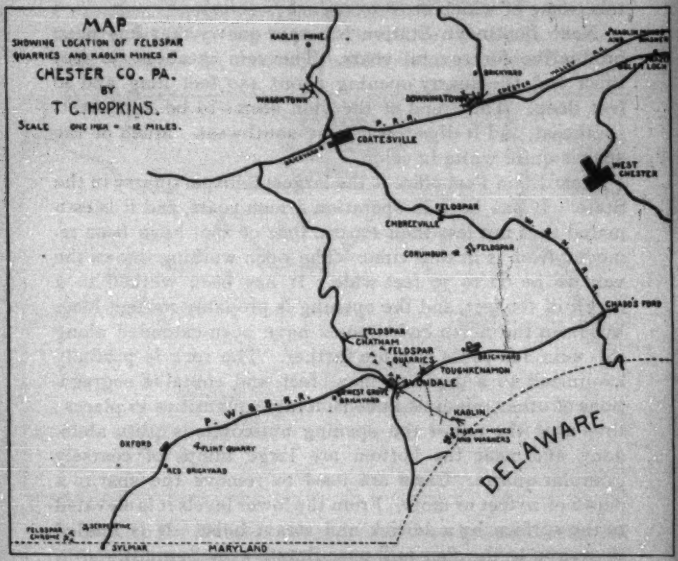
A feldspar quarry, known as the Sharpless quarry, about a mile south of east of Glen Mills, was operated a number of years ago, but is now idle. The spar contains large segregations of quartz and a great many large muscovite crystals, some of which are 8 to 10 inches across.

Near Boothwyn Station is a spar quarry that has been productive for several years. The vein is about 30 feet thick and the quarry opening about 150 feet long and 40 feet deep. The trend of the vein seems to be northwest-southeast, and it dips toward the southwest. Much of the spar is quite white in color.

Near Elam Post-office is the largest feldspar quarry in the State. It has been in operation fifteen years, and it is estimated that not less than 100,000 tons of spar have been removed from it in that time. The open working shows the vein to be 60 to 70 feet wide. It has been worked to a depth of 100 feet, and the opening is probably 200 feet long, but from the north end tunnels have been extended along the vein 100 yards or more further. The rock is partially kaolinized to a depth of many feet, and contains segregations of other minerals in considerable quantities in places; thus near the top of the opening muscovite is quite abundant, and near the bottom are large lumps of coarsely granular quartz. Carts are used to remove the spar to a depth of 20 feet or more. From the lower levels it is elevated to the surface by a derrick and steam hoist. It is hauled by wagon to the spar mill near Brandywine Summit.

Northeast of Unionville are several small feldspar quarries operated by companies outside of the State, one a Trenton company and one at Wilmington, Del. Feldspar was quarried from four openings during the present season, and there are not less than a half dozen other openings from which spar has been removed within the last few years. The openings are comparatively shallow, and appear rather as pockets than veins, although probably enlarge-

ments of veins, but the country rock has so disintegrated that the spar lies in the loose disintegrated material, and the vein walls are not clearly defined. The rock is a mica schist bordering on serpentine, and it appears that some of the quarries are within the serpentine area. Muscovite and biotite are quite abundant in places, and there is considerable diffused quartz, but no large masses were observed. These quarries are near the corundum mine,



where corundum was mined in considerable quantities several years ago.

The spar quarry at Embreeville is on the W. & N. railway, about 100 yards north of the Embreeville station. The vein, which is about 10 feet thick, crosses the railroad, and has been quarried on both sides of the railroad track. The vein appears to correspond in dip and strike to the garnetiferous mica schists in which it occurs, namely,

dipping 40° south, 60° east. The spar is nearly snow-white, slightly stained by dendrite markings in places. The analysis indicates a soda orthoclase with a slight admixture of a lime-bearing feldspar and considerable free quartz.

ANALYSIS OF FELDSPAR FROM EMBREEVILLE QUARRY.

SiO_2	67·46
Al_2O_3	21·76
CaO	1·67
Na_2O	5·96
K_2O	4·28

The quarry was first opened in 1885, and in 1886 produced 200 tons of spar ("Min. Res.," 1886, p. 701). The continuation of this vein southwest from the quarry is distinctly shown by the numerous outcrops at different points along the line of strike.

In the vicinity of Avondale there are four active and three idle feldspar quarries. They are all in pegmatite veins in mica schist, some of them in the immediate vicinity of limestone outcrops. The spar has a better defined pegmatite structure than that at any of the other quarries, that is, the quartz occurs intergrown on both cleavages of the orthoclase, giving the regular angular appearance of the ancient hieroglyphics.

Two of the most productive quarries are close to the village of Avondale on the north side of the village. The upper 10 feet of the spar are much decayed. The vein varies in width from a few feet to 31 feet. These quarries produced between 6 and 7 tons per day each during the summer of 1898.

About one and one-quarter miles north of Avondale is a large feldspar quarry with an opening about 120 by 40 by 35 feet in a pegmatite vein which has a general southwest-northeast direction and dips to the southeast. It was operated the first part of 1898, but was idle in the latter part of the summer. It has produced considerable feldspar, and, judging from the dump, there was considerable material handled to produce it.

There is another active quarry on the north side of the

Chatham pike, a mile or more northwest of Avondale, on the Thompson place, and another about half a mile further north, on the Dicky place, both of which contain typical graphic granite, and both of which were operated during the past summer.

The spar in the quarry near Chatham, about three miles west of north from Avondale, is different in appearance from that at Avondale. It has a nearly white color, and the quartz, instead of occurring along the cleavage planes of the feldspar, as in typical pegmatite, is segregated in large masses. The spar contains more plagioclase, and hence runs higher in soda and lime than that at Avondale.

The feldspar quarries near Sylmar, in southern Chester County, have considerable scientific interest in that, to the best of my knowledge, they are the only feldspar quarries in the world that occur in a serpentine rock, except, perchance, some of those near Unionville, Pa. The latter, if in the serpentine at all, are in the border close to the mica schists; but in the Sylmar locality the spar is in the midst of a large area of serpentine, which outcrops on all sides of it. Small feldspar veins occur in serpentine elsewhere in the State, but, so far as known to the speaker, none of the others are of sufficient size to have any commercial value. The spar in these quarries is not a graphic granite, as there is no quartz present, and some of the spar has no well-defined cleavage. It consists of orthoclase, along with some albite and other plagioclase, associated with muscovite, hydromicas, hornblende and asbestos. The spar is well preserved, showing little evidence of decay, beyond a dull cleavage surface in places, and is frequently marked with a beautiful dendrite coating. The largest one of the quarries lies on a vein running nearly northwest and southeast (N50°W.). The opening is 30 feet wide, 35 feet deep and 150 feet long. At the south end the vein divides into two (whether permanently or whether only separated by a horse of serpentine is uncertain). Near the north end is a small vein branching off at nearly right angles.

The second quarry is about 200 yards southeast of the first on the line of strike of the vein, and probably on the

same vein, but there are no outcrops between the two to connect them. Chromite mines are operated nearby.

Where did this serpentine feldspar come from? A possible source is from a gneiss or schist underlying the serpentine, or from a former overlying one. Or it may have been a segregation in the rock from which the serpentine was derived; or it might have been produced from the rock from which the serpentine was derived.

As long as the origin of the serpentine itself is a question of dispute, we can hardly hope to satisfactorily explain the origin of the spar.

The feldspar quarries at Chadd's Ford and Fairville were not visited by the speaker, as he did not learn of their existence until he left the field work.

There is an abandoned feldspar quarry in Montgomery County, on the east bank of the Schuylkill River, between Lafayette and Spring Mill.* The quarry was opened in 1886, and 30 tons of spar removed and sold to the potteries in Trenton. The crude spar brought $5 per ton in Trenton.

The feldspar is orthoclase, with white granular quartz and large masses of biotite. It dips northward beneath the gneiss, and strikes transverse to the gneiss. The feldspar is at least 45 feet thick.

The deposits of feldspar that have been opened in Delaware and Chester Counties are probably but a fraction of the veins that might be worked, and Pennsylvania is likely to be a producer of feldspar as long as there is demand for the same, and the price is high enough to warrant exploitation.

The price of the crude feldspar, as it comes from the quarry, varies from $3.75 to $4.25 per ton, f.o.b. The price for the ground spar is about double that of the crude.

The production of feldspar in the State cannot be definitely stated, as some of the producers refuse to give the output of their quarries. A careful estimate by the speaker puts the amount for the year 1898 at 9,000 tons, which is

* Described by Prof. O. C. S. Carter in "Proc. Am. Phil. Soc.," Vol. 29, 1891, p. 49-50.

probably a little less than the actual output, as no estimate was made for two of the companies from which no data were obtained.

KAOLIN.

One of the most common commercial products that result from the decay of feldspar is kaolin. The feldspars are compounds of silica with alumina and one or more alkalies. The alkalies are more soluble than either the alumina or silica, and on exposure to the atmosphere and meteoric waters they are leached out, probably by the action of carbonic and other acids, and at the same time water is added. In the process more or less silica is set free or forms new combinations, as the kaolin molecule has but one-third as much silica as the orthoclase. A hypothetical reaction, in which orthoclase is changed to kaolin, is as follows: $\underset{\text{(Orthoclase.)}}{K_2O,Al_2O_3,6SiO_2} + CO_2 + 2H_2O = \underset{\text{(Kaolin.)}}{Al_2O_3,2SiO_2,2H_2O} + K_2CO_3 + 4SiO_2$.

The potash is carried off in solution, and the kaolin and at least a considerable portion of the silica remain. Under varying degrees of temperature and pressure feldspars may undergo other transformations and different minerals result.

Pure kaolin, or kaolinite, contains 46·5 per cent. silica, 39·5 per cent. Al_2O_3 and 14 per cent. H_2O, but absolutely pure minerals do not occur in commercial quantities. Kaolin, being a secondary mineral, is liable to have not only the mineral impurities of the original feldspar, but an excess of silica that would result from perfectly pure feldspar, and frequently portions of undecomposed feldspar. There may also be impurities carried in by the meteoric waters.

There are two classes of kaolins, one the residual kaolin, that occurs in the position of the original feldspar as a residuum from the disintegration of the feldspar, the other a transported or sedimentary kaolin caused by streams washing away the residual kaolin and depositing it as sediment at some other locality.

Of the two classes of kaolins, the second or transported ones are liable, under the most favorable conditions, to be

purer than the residual ones, as the wonderful sorting power of water separates all the coarser and heavier particles contained in the residual material. However, the sedimentary deposits are liable to have impurities from other localities of material of the same degree of fineness, or of soluble materials, or materials that have segregated in or on the clay after its deposit. Hence the residual kaolins, while they generally have a smaller percentage of pure kaolin, are more likely to be a source of commercial supply than the sedimentary, because the foreign matter is mostly coarser material that can be separated by a mechanical process. The sedimentary kaolins, while frequently mixed with mechanically inseparable materials, do sometimes occur in commercially pure form, so that they can be used without any refining process, while others can be used like the residual kaolins after refining or washing.

There are several other minerals closely related to kaolin in composition and physical characters, so closely related, in fact, that they might, for the most part at least, be classed as varieties of kaolin rather than as separate materials. Some of these varieties have considerable local interest, some are of commercial importance, but most of them are of interest only to the mineralogist and are unknown to the tradesman. The chemical relations of these minerals to each other and to kaolin are best known by tabulating them:

Kaolin	$Al_2O_3.2SiO_2.2H_2O$	= Al_2O_3 39·5 p. c.,	SiO_2 46·5 p. c.,	H_2O 14·0 p. c.
Halloysite	$Al_2O_3.2SiO_2.2H_2O$ + aq	= Al_2O_3 36·9 "	SiO_2 43·5 "	H_2O 19·6 "
Newtonite	$Al_2O_3.2SiO_2.5H_2O$	= Al_2O_3 32·7 "	SiO_2 38·5 "	H_2O 28·8 "
Rectorite	$Al_2O_3.2SiO_2.H_2O$	= Al_2O_3 49·5 "	SiO_2 50·0 "	H_2O 7·5 "
Cimolite	$2Al_2O_3.9SiO_2.6H_2O$	= Al_2O_3 23·9 "	SiO_2 63·4 "	H_2O 12·7 "
Montmorillonite . .	About $Al_2O_3.2SiO_2.H_2O$, but varies.			
Pyrophyllite	$Al_2O_3.4SiO_2.H_2O$	= Al_2O_3 28·3 "	SiO_2 66·7 "	H_2O 5·0 "
Allophane	$Al_2O_3.SiO_2.5H_2O$	= Al_2O_3 40·5 "	SiO_2 23·8 "	H_2O 35·7 "
Collyrite	$2Al_2O_3.SiO_2.9H_2O$	= Al_2O_3 47·8 "	SiO_2 14·2 "	H_2O 38·0 "
Schroetterite	$8Al_2O_3.3SiO_2.30H_2O$	= Al_2O_3 53·1 "	SiO_2 11·7 "	H_2O 35·2 "
Indianaite (nearly kaolin)		Al_2O_3 38·7 "	SiO_2 44·7 "	H_2O 15·0 "

Any of the above are liable to occur in small quantities associated with kaolin or allied minerals, but the only ones known to occur in commercial quantities are indianaite, halloysite and newtonite. Halloysite is mined in Ken-

tucky, South Carolina and Georgia (*Eng. and Min. Jour.*, October 1, 1898).

There are numerous other sub-varieties, such as smectite, bole, pholerite, guembelite, samoite, etc., which are mostly local in their occurrence and importance.

Both the residual and sedimentary kaolins occur in Pennsylvania in two rather widely separated fields—the residual ones in Delaware and Chester Counties and the sedimentary ones in Cumberland, Franklin and York Counties, and possibly elsewhere. There are eight kaolin-washing establishments in operation in the two fields, if we include one that is temporarily idle and one that has but recently started.

The residual kaolins occur in Delaware and Chester Counties. There were formerly two kaolin-washing plants operated in Delaware County, but now there is none. There are three in Chester County.

In the residual kaolins of Pennsylvania the most common impurities are undecomposed feldspar, mica and quartz, which are almost wholly removed in the washing or refining process, except, at times, some of the quartz, which is so finely divided that it is carried over with the kaolin. In some of the mines there is a small percentage of iron oxide in the clay that is not removed in the washing. Ordinarily, the yellow portion containing the iron oxide is thrown aside or put in as a lower grade. But on account of its usually greater plasticity it is advisable to use some of it at times to render the clay tough enough to handle.

Washing the Kaolin.—The method used in the Chester County washing plants is that with the common log washer and troughs. The process is based on the marvellous sorting power of water. One of the essential parts of the process is a horizontal shaft, set at intervals with short iron or wooden arms, which shaft rotates in a rectangular or semi-circular trough, into which the clay and water are thrown. The arms on the rotating shaft break up the lumps of clay and stir it into a slip or mortar, which is carried away by the running water through a long trough, which is frequently about 700 feet long; but for convenience this is cut in sections, which are placed side by side, and the current

follows a zigzag passage. The aim is to so regulate the current of water that all the kaolin will be carried along and the other materials dropped in the bottom of the trough. The greater portion of the coarse sand and heavy particles are dropped in or close to the washer, and one or more sand wheels are inserted to remove it and prevent it from clogging the troughs. At intervals the troughs are opened and the sand scraped out. The water carrying the kaolin in suspension passes from the troughs into settling tanks, where, after the kaolin settles, the clear water is removed and the kaolin slip pumped into a hydraulic filter press, where most of the water is squeezed out.

The kaolin comes from the filter press in large cakes, which are further dried either in racks in the open air or on a dry floor. In many places the dried kaolin is shipped in sacks, but the Chester County producers load the material loose in the car.

Kaolin, Pa.—One of the oldest kaolin-producing localities in the State is that near Kaolin Post-office, in Chester County, where kaolin has been mined and washed since 1839. At present there are two companies operating mines, each turning out about 40 tons of refined kaolin per day. Nearly all the kaolin from this locality is shipped to the large potteries in East Liverpool, Ohio, and Trenton, N. J. Both of the companies make a partial use of the by-products. One company screens the sand, pulverizes it and sells it to the potters for ground flint. The other company uses the sand for making silica brick for furnace use. Yet, despite the usage made of the sand, there is a large accumulation of it at both works.

The kaolin deposit is about 40 to 50 yards wide, with at least one parallel vein, and possibly others. It is all mined from the circular shafts with the temporary timbering. The deepest shaft sunk was 130 feet, but even though the kaolin deposit is deeper than that, most of the shafts are sunk less than 100 feet, as it is claimed that the expense of hoisting the material more than that distance is too great to follow with profit. As all the openings are filled with waste material, except the ones in which work is carried on,

there are no exposures except the kaolin in the bottom of the one or two shafts in actual operation. Several large boulders of coarsely crystalline, partially disintegrated giant granite have been left on the surface in one place, and is the only solid rock in sight at the mines. The kaolin is a decomposed pegmatite vein in the mica schists, the structure of the kaolin showing its pegmatite origin. The apparent trend of the vein, as shown by the openings made by the two companies, is northeast-southwest, but neither the width nor the lineal extent can be accurately determined from the openings made, yet they are sufficiently numerous and scattered to show a large deposit of kaolin of good quality. Near the surface the kaolin has a buff or yellow tint due to the admixture of yellow soil from other rocks. The yellow color extends several feet below the surface in most places, although in a few places the white clay is exposed on the surface.

The Hockessin, Delaware, kaolin mines and works are but two or three miles south of east from the kaolin mines described above, and are closely related to them in the character of the kaolin and the mode of its occurrence.

Brandywine Summit.—To the reading public the Brandywine Summit kaolins are better known than any others in the State, because they are the only ones that have been described in the State reports. The Annual Report for 1885 of the Second Pennsylvania Geological Survey gives an illustrated and quite a detailed account of the kaolin deposits and washing plants at that place. They are now idle and have been for many years. As at Kaolin, there were two companies, each of which a few years ago produced kaolin of good grade in large quantities. Both the companies are in existence yet, under the same, or nearly the same, firm names with different personnel, but one is now producing feldspar, as already mentioned under that subject, and the other is manufacturing high-grade building brick from the refuse material from the former kaolin mines.

The reason offered for the abandonment of kaolin washing is that the best material has all been removed from near

the surface and, owing to the abundance of water in the mines and the low price of kaolin, it is no longer profitable to work the deeper parts of the deposit. One company ceased preparing kaolin seven years ago and the other, three years ago. There is thought to be large quantities of good kaolin yet remaining, but not in position to be worked with profit at the present time.

On the Crawford estate, about a mile southeast of Elam Post-office and two miles or more from Brandywine Summit, is a deposit of white clay of considerable extent. It has not been refined for use in china-making, but was formerly used in the crude state for making fire-brick and some of it shipped in the crude state to other points. The material has not been mined for several years, and so far as could be determined from the small exposures now to be seen, it occurs in a sedimentary deposit of recent age. The clay is said to be highly refractory and produced fire-brick of good quality, and was sought after for furnace linings. It is quite probable, from the appearance of the clay, that with proper selection and washing it might produce a fair grade of china clay. Near the clay deposit there is a large sand bank from which considerable sand has been shipped.

Glen Loch.—About a mile and a half north of Glen Loch Station, on the north side of Little Chester Valley, are a kaolin mine and washer that have been in operation for four years, except during the present summer (1898), when they have been temporarily idle. The mine is near the contact of the Chester Valley (Ordovician) limestone and the North Valley Hill sandstone (probably Cambrian). The sandstone outcrops a short distance north of the mine and the limestone a short distance south, but neither rock is exposed at the kaolin opening. There are numerous large masses of coarsely granular white quartz in and near the kaolin, and large masses of granular quartz containing crystallized wavellite. Near the kaolin mine is an old iron mine from which large quantities of limonite were removed years ago. Less than 100 yards north of east is another deep shaft that furnished some iron ore and a rare mineral, *cerulleo-lactite*.

The kaolin is exposed near the surface at the mine, but the owner states that exploration shafts show it to sink rapidly beneath a thick covering of loose material of sand and rock fragments both east and west from the opening. The same authority states that the kaolin vein dips north into the hill and hence runs under the iron ore which lies north of it.

The Glen Loch kaolin bears a remarkable similarity to the white clay deposits of South Mountain in its geological position, but differs quite materially in its chemical composition, as may be seen on comparing the analyses:

ANALYSES OF GLEN LOCH AND SOUTH MOUNTAIN KAOLINS.

	Glen Loch Kaolin. Per Cent.	South Mountain Kaolin. Per Cent.
Silica	51·90	73·80
Alumina	31·29	17·30
Lime	tr	·00
Iron Oxide	tr	·35
Magnesia	1·52	1·18
Potash	4·01	2·49
Soda	2·99	·20
Loss on ignition	8·90	4·69
Total	100·61	100·01

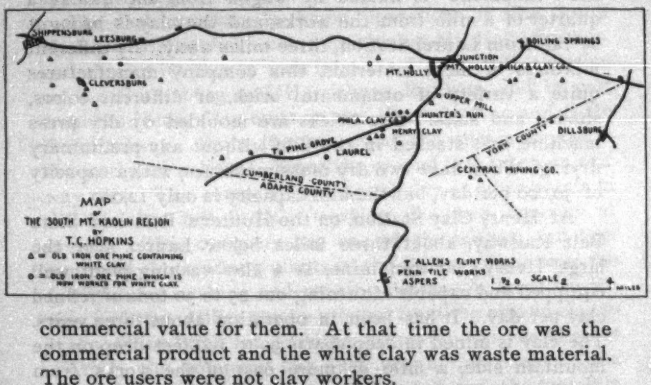
In Chester County, about two miles north of Wagontown, is an abandoned kaolin mine that was operated twenty years or more ago. A large circular opening about 100 feet in diameter and 60 feet deep shows that considerable work was done here at one time. The country rock is a hornblende gneiss.

SOUTH MOUNTAIN WHITE CLAYS.

Probably the most extensive deposits of white clay in Pennsylvania are to be found in the South Mountain region in Cumberland, Franklin, Adams and York Counties, between Dillsburg on the east and Shippensburg on the west. The most extensive developments have been on the Gettysburg and Harrisburg Railway, south of Mt. Holly, and on the Hunter's Run and Slate Belt branch railway.

Historical.—The occurrence of white clays in this region has been known for many years, but it was only a few years

ago that any attempt was made to put them to commercial use. There are a great many large iron ore mines in which the ore is associated with the white clay. In nearly all these ore mines, which were worked quite extensively years ago, the white clay was found, sometimes underneath the ore and sometimes overlying it. In the latter case it was necessary to remove the clay to get the ore, and it was dumped out as so much waste material, just as the ore is thrown aside at the present time where it interferes in the removal of the clay. In the reports of the Second Geological Survey of Pennsylvania bearing on this region there is mention of the white clays at nearly all the iron mines described, but there is no intimation of any possible



commercial value for them. At that time the ore was the commercial product and the white clay was waste material. The ore users were not clay workers.

The first attempt to make commercial use of the clay was about six years ago, when the Penn Tile Works was established at Aspers, about the same time or shortly after the brick works at Pine Grove began operation. About three years ago two clay-washing plants were established on Mountain Creek, between Pine Grove and Mt. Holly Springs. More than a year ago a clay-washing plant was started at Latimore, and this year, 1898, another large plant started at Mt. Holly Springs. There are other parties exploiting the region for good clays.

Mr. J. W. Ivery has probably done more to develop the clays of this locality than any other individual. It was he that started the works at Pine Grove, at Aspers, and one of the works near Hunter's Run, and he is now Superintendent of the works just started at Mt. Holly Springs.

The factory at Pine Grove manufactures ornamental bricks of different kinds. The white clay, along with some colored clay, is used simply as a bond, the body of the material being a black slate for their reddish-colored bricks, and a greenish talcose schist ("soapstone") for the light-colored ones. The slate is brought to the works by railway from the slate quarry about three miles southwest of the works; the "soapstone" is hauled by wagon from the quarry a quarter of a mile from the works, and the clay is brought by rail from Laurel Station, three miles away. By different mixtures of these materials, this company manufactures quite a variety of ornamental brick, of different colors, shades and sizes. The bricks are moulded by dry press machine, and stacked in the kiln without any preliminary drying. They have two dry press machines, with a capacity of 30,000 per day, but the kiln capacity is only 12,000.

At Henry Clay Station, on the Hunter's Run and Slate Belt Railway, about three miles below Laurel, near the large Henry Clay iron mine, is a clay-washing plant well equipped and capable of turning out 25 to 30 tons of refined clay per day. It has been in operation about three years. The clay is mined in deep shafts 90 to 100 feet deep on the mountain side, a mile or more east of the works, from which point it is hauled by wagon to the works.

At Crane's Siding, on the H. R. & S. B. Railway, one mile above Hunter's Run Station, is a clay-refining plant that has been in operation about three years, and turns out about two carloads, 50 to 60 tons of refined clay per day. The clay is obtained at the long since abandoned Crane iron ore mine, where it underlies the ore, but lies at a high angle on the steep south slope of South Mountain. The mining is done in underground galleries, and the clay run out on tram cars and tipped on a platform from which it is wagoned to the works. The refined clay is shipped to wall-

paper manufacturers and potters. They have also prepared some brown clay from the sludge from the iron ore mine. This branch of the industry has apparently been abandoned.

Near Latimore Post-office, on the south side of South Mountain, six miles south of Dillsburg, the nearest railway point, a clay-washing plant was recently constructed, and has washed 100 tons or so of clay, but the product has not been entirely satisfactory, and the company has not yet put any on the market. Part of the clay is mined near the works, and part is brought from another mine two miles or more north of the works. It is all very short in the grain, apparently high in silica.

The last company to begin operations in the South Mountain district has located its plant at Mt. Holly Springs, and obtains its clay in part from the Upper Mill, a station on the Gettysburg and Harrisburg Railway, and in part from the Henry Clay mine on the Hunter's Run and Slate Belt Railway. From the first point the clay is moved to the works on wagons. From the second it is taken on railway cars. The company has leased clay at other points in the vicinity, but is only working the two deposits at present. This company has one of the largest and best equipped clay-working plants in the State. They have the facilities for washing and refining the clay in large quantities, and they utilize the by-product from the refined clay to make white brick for building purposes. At the time of writing, the company has just begun operations. The machinery was first started in July, 1898, and the first kiln of brick was burnt in September. They expect to refine clay for the wall-paper, the pottery and tile trades, and use the screenings for making high-grade brick.

The refining process is different from that in the Chester County washing plants. In place of the log washer, large iron blungers are used to disintegrate and stir the clay to a thin slip. It is run first into large cedar tanks, where the coarse materials are separated and the clay slip pumped into other settling tanks, from which it is pumped into the hydraulic presses. The company now has nine blungers,

twenty-two large cedar tanks and eight filter presses in operation.

The Clays.—The clays of the South Mountain area are sedimentary clays and not formed from the decomposition of feldspar in place like the kaolins of southern Chester County. They are probably of Cambrian age, occurring near the contact of the South Mountain sandstones and shales of supposed Cambrian age, and the Cumberland Valley limestone of Lower Silurian or Ordovician age. The strata are so broken, crumpled and disintegrated that it is not possible in many places to accurately locate the position of the clay beds in the section. In so far as they can be located, they appear to be at or near the top of the supposed Cambrian rocks. They are closely associated with extensive deposits of iron ore. There are a great many large ore mines that were operated extensively a few years ago, and in all these mines that occur in or close to the mountains the white clay occurs in large quantities. In many places the clay is stained in streaks, bands and irregular patches by contact with the yellow, brown and red iron oxides. In some places the ore underlies the mass of the clay, and in other places it overlies the clay, which is the result of the folding of the strata. The iron accumulated on the top of the clay originally, probably derived in part from the overlying limestone, and in part from the associated schists. The meteoric waters percolating through the limestone leached out the iron and deposited it at and near the less permeable clay and slate beds underlying. Further disintegration of the rocks, and later folding and crumpling, aided to mix the ore and clay along the contact, and in the folding of the strata in places the folds were pushed beyond the perpendicular, thus reversing the relative position of the strata on one side of the fold. It may be observed that on the north side of the mountains, or the south side of the valley, the ore underlies the clay, while on the south side of the mountain, or the north side of the small valley, the ore overlies the clay. This may be seen at the Crane Siding mine, which is on the north side of the valley, and where the ore has been worked from the surface openings, and now the

clay is being mined from below and behind the ore bodies. The same condition prevails on the mountain east from the Upper Mill, where Mr. Musser has made several openings in the clay between the ore and the mountain, and while the openings are on the hillside above the ore openings, the strata dip south at a higher angle than the slope of the hill, so that the clay beds are carried underneath the ore.

At the Henry Clay mine and the mine at Laurel the ore dips under the clay at a high angle, and has been worked back until there was a covering of 30 feet or more of clay over the ore. The same condition prevails at the mines of the Reading Iron Company, south of Boiling Springs, where the underdipping ore has been worked back by open cut until the overlying clay was too thick to remove, and then the ore is removed by underground drifts run down the incline underneath the clay.

The structure is rendered more complex and difficult because (1) the rocks in some places are more resistant and the folds have not been overturned, and (2) in several places there have been faults or vertical misplacements of the strata. The difficulties are increased by the scarcity of the exposures of the rocks *in situ*, which is due to the fact that the quartzite rock is quite brittle, and hence much fractured in the folding, thus breaking into loose masses of fragments on exposure, and the slates weather into clays, which, on the steep hillsides, creep down over the surface rocks for long distances. Therefore, while the general structure of the mountains is a series of overturned folds pushed over towards the north, the irregularities due to faults and variations in the strata, further modified by weathering and eroding agencies, render the structure so complex that it is difficult to follow the different strata for any great distance with accuracy. Hence correlation of the different deposits is attended with considerable uncertainty. In the front range, wherever the sandstone or quartzite was observed *in situ* by the speaker, which was in several places, it had a uniform east-of-south dip, but in many of the old ore mines apparent northerly dips are recorded. These apparent variations may be caused by secondary and tertiary folds parallel

with the main one or by the creep of the clay on the hillsides.

The following observations, made by an assistant on the State Geological Survey, fourteen years or more ago, may be of interest in this connection, and as they may not be accessible to all our readers, we take the liberty of giving them.* Owing to the rapid weathering of clays, good exposures made at the time the mines were in operation were quickly obliterated and cannot be observed now, hence the value of observations made years ago as hints and helps now in exploiting the clays which were then "barren clays."

In the Big Pond banks† the southern part of the openings showed 22 feet of white clay (p. 1441).

The George H. Clever bank showed white, yellow and red clays associated with the wash ore (p. 1442).

The Pine Grove bank No. 1 has a large horse of white clay, which still (1886) occupies a place in the east workings, and excavations on both sides of this generally barren dome of clay show excellent ore. The north side of the cut shows a conspicuous amount of black clay (p. 1449).

At the Dunbar mine (R. Boyer) the main tunnel seems to have cut three distinct ore beds, none of them over two or three feet in thickness and separated from each other by an immense amount of barren clay (p. 1460).

At the Crane Iron Company's banks (Phil. Clay Co.) "the stripping, under the most favorable circumstances, amounts to about 20 feet, while toward the mountain, where their best ore is found, it is simply enormous and consists mostly of sandy blue and white clay."

A bore hole for water at the Lehman mine disclosed 340 feet of ore, 40 feet of blue clay, 30 feet of white clay and 25 feet of mountain clay to the Potsdam Sandstone, a total

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*These are quotations and abstracts from the report on the iron ore mines and limestone quarries of the Cumberland-Lebanon Valley, by E. V. d'Invilliers, in the "An. Rept. Geol. Surv. of Pennsylvania," 1886, Pt. IV, pp. 1411–1517. The same report is summarized by J. P. Lesley in the "Summary Final Report, 1892, of the Pennsylvania Geol. Surv.," Vol. I, but the summary omits most of the references to the clay.

†See map on page 23 for location of the different banks.

depth of 435 feet. A heavy white clay shows on the western extremity of the cut, similar to that seen at the Crane mine (p. 1462).

At Ege bank (Big Creek) "the gangue material accompanying these ores, and especially that thrown out of the trial pits, is frequently a greenish talcose slate called soapstone by the miners, many of whom state that the base of the ore-bearing clays is a reddish slate, beneath which no ore, but occasionally white barren clay, is found."

At the Heck bank, north of the wash ore deposit, lump ore is said to have been tested by drifts run into the mountain side 25 or 30 feet, beyond which nothing but white clay is found.

At the Muslin bank an "80-foot shaft was sunk in the center of an otherwise promising ore pit, which, however, only developed a stiff white clay through the entire distance" (p. 1483).

The developments at the present time, in fact, the developments twenty years or more ago, are sufficient to show that enormous quantities of beautiful white clays occur in this region, but they are associated with still larger quantities of lower grade clays, that are stained with the associated iron ores. The works erected during the last few years show that the commercial importance of the clays is now established. The developments will be still greater as the quantity and qualities of the clay become better known. Owing to the association of the iron ores with the clays, large quantities of it will be found in all the localities that are stained with the iron oxides, and the company with sufficient capital to use these lower grade clays along with the higher grade will have the advantage.

White clays in the Cambrian rocks are not peculiar to this portion of the South Mountains, but occur in other districts as well. Similar-looking clay has been found, but only slightly developed in rocks of the same age on Neversink Mountain, at Reading, Pa., where some one* has

* There was no one at the place at the time of my visit, August, 1898, and I could not learn the name of the owner.

opened a deposit of white clay similar in appearance to that at South Mountain.

The Glen Loch kaolin mines may be near the same horizon. A white clay somewhat similar in character, but in smaller quantities, occurs with some of the iron ores in the Nittany Valley. This is probably at a higher horizon, but may have the same source.

Large quantities of white clay are reported at various points along the Great Valley region from Massachusetts to Alabama.* Deposits of the white clay in Lehigh County are said by Professor Prime to be derived from disintegrating damourite slates, and analyses of the clays show close relation chemically to the Cumberland County clays just described.

The Uses of Kaolin.—Kaolin is used in the manufacture of chinaware, hence the name china clay.† It serves to furnish a highly refractory white body for the chinaware. It serves a similar purpose in the manufacture of white tiling, white brick and white clay ware of all kinds. Kaolin, or white clay, is used in large quantities in the manufacture of wall-paper and sized paper, the paper trade taking about the same quantity as the pottery trade. It is used in small quantities for other purposes, but the bulk of the product goes to the potteries and the paper manufacturers.

The output of the Pennsylvania kaolin mines for 1898 is not far from 20,000 tons. As some of the producers will not give their production, this is partly an estimate, but a conservative one, based on observations, reports of railway officials, and a comparison of the working force and facilities of the companies not reporting with those that did give their output.

The prices vary from $10 per ton for the best grade kaolin to $6 or $7 for inferior grades. The prices of one of

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* See "Tr. Am. Inst. Min. Eng.," Vol. 3, 1874-5, p. 410. The Brown Hematite Deposits of the Great Valley, by Prof. F. Prime, also "Proc. Amer. Phil. Soc.," May, 1872, and January, 1873, articles by Prof. J. P. Lesley.

† Some writers distinguish between kaolin and china clay by calling the crude product kaolin and the refined product china clay, but the distinction is not scientific nor is it universally adopted.

the companies are, No. 1 kaolin, $10 per ton, f. o. b.; No. 2, $8; No. 3, $7. However, the active competition among the different dealers causes a considerable variation and fluctuation in prices.

ANALYSES OF PENNSYLVANIA KAOLINS.

	SiO_2	Al_2O_3	H_2O	CaO	MgO	K_2O	Na_2O	Fe_2O_3
1. Glen Loch, Pa.	51·90	31·29	8·90	tr	1·52	4·01	2·99	—
2. Brandywine Summit . .	71·02	19·72	7·04	·32	·03	·27	—	1·58
3. " " .	67·71	20·53	7·78	·39	·04	·29	—	3·12
4. Chestnut Hill	67·10	20·10	5·90	·10	·70	2·	tr	3·9
5. E. Nottingham	46·34	36·32	13·75	·04	tr	·77	tr	·64
6. Kaolin, Pa.	—	—	—	—	—	—	—	—
7. Upper Mill, Mt. Holly .	84·05	9·44	2·18	·23	1·35	2·37	·28	·28
8. " " .	73·80	17·30	4·69	—	1·18	2·49	·20	·35
9. Mt. Holly Springs . . .	73·30	17·43	4·68	·02	1·28	2·99	·17	·37

No. 1 made by F. A. Genth, 2 and 3 made by J. B. Britton, 1874, 4 and 5 made by F. A. Genth.

Nos. 7, 8 and 9 made in chem. lab. State College; No. 7 the crude kaolin, 8 the refined kaolin, 9 refined kaolin mixture from Upper Mill and Henry Clay mine.

Stated Meeting, March 8, 1899.

SOME FEATURES OF THE STRUCTURAL DESIGN OF BUILDINGS.

By Wm. H. Burr,
Columbia University, New York.

(*Concluded from vol. cxlvii, p. 430.*)

Experience in modern high building construction during the past three or four years has shown conclusively that although such buildings are from one point of view fire-proof, their interiors are frequently very combustible. Both New York City and Pittsburg, as well as Chicago, can show conflagrations in which steel frames and fire-proof floor construction were but indifferent protection, at least to the interiors of the buildings. It has been conclusively demon-

strated that if a building is to be fire-proof in the true sense of the word, its interior trim and furnishing, so far as possible, must be of non-burning materials. Further than that the same experiences have demonstrated with equal conclusiveness that the iron and steel members of the building frame must be substantially protected from the immediate exposure to high temperatures. This end is not difficult of accomplishment. It is attained with reasonable facility by surrounding beams, columns and other metallic members by casings of terra-cotta or tile shapes so formed to fit the metal that, when once in place, the casing is continuous and sufficiently well locked and secured to retain its position under any ordinary fire experience. This is already accomplished in well-designed buildings, and has, indeed, become in the best practice quite an ordinary procedure. These terra-cotta or other equally efficient fire-proof casings should not be of a flimsy or unsubstantial character, but in general should be from 4 to 8 inches in thickness. They are frequently put on in two layers. It is essential that the material should be such as not to crumble and fall away under the temperatures produced in a burning building.

On the whole, experience seems to indicate that tile or terra-cotta partitions are less satisfactory under the conditions of a conflagration than steel studding with plastering on wire netting, as they are liable to crumble and go to pieces, particularly if struck by water, but such indications cannot yet be considered conclusive.

Perhaps that portion of fire-proof construction, requiring the most careful consideration from a structural point of view, is the floor of a building. The floors are horizontal and cover large areas, and if a fire is started it attacks them in such a way as to produce the most aggravated effects possible. Their horizontal position and large areas contribute to this result. At the same time they carry the own weight of the greater portion of the building and its contents and the moving load. They must, therefore, not only be fire-proof, but they may be subjected to heavy loading, while their fire-proof qualities are receiving the most severe tests. Their carrying capacities must, therefore, remain

practically unimpaired while they are subjected to simultaneous high temperatures and impact of fire streams. Many investigations of an empirical character have been made in order to determine materials and combinations of materials which can be depended upon to afford the desired security; and it may fairly be said that these investigations have at the present time been crowned with a considerable degree of success.

Probably the earliest investigations of the carrying and resisting capacities of fire-proof floors were those carried on in Denver, in 1890. In those investigations both hollow tile and concrete floors were subjected to test. The most complete series of such investigations of actual fire proof floors was that conducted by the Department of Buildings of New York City, in 1897, which covered a number of systems of construction, among which were all the more prominent ones used at the present time. The general method of procedure was the construction of a floor of any given design over a furnace area 14 x 16 feet or about 14 feet square. The walls of this furnace were of brick and two grates extended over the entire interior floor, one about eighteen inches above the other, on which were piled the wood fuel used for the high temperatures required. Each type of floor was constructed as a roof to the furnace and of the actual thickness and materials used in regular building construction. The various types of floor were constructed between rolled steel beams spanning the longest dimension of the furnace and from 4 to 5 feet apart, giving about the ordinary span found in fire-proof floors. The chief materials used were concrete, either cinder or stone, of various proportions and hollow tile of the usual terra-cotta character. The concrete was usually employed in combination with wire netting, reinforced with heavier wire rods about $\frac{7}{16}$ inch in diameter, or with some other light metal device of a character more or less similar to that described. In some cases the plastered ceiling was held on netting either suspended from a concrete arch above or secured by other means. In other cases, as in the Rapp system, the plaster on the under side of the floor, corresponding to the ceiling of a room, was ap-

plied directly to brick surfaces or others of a similar character. In all cases the lower flanges of the steel supporting beams were protected by plaster, or concrete, or terra-cotta shapes or plates so formed as to fit the flanges. The concrete used was made frequently with cinder, but sometimes with stone or gravel, and in one case at least the material between the rolled beams was made chiefly of plaster-of-Paris and wood chips, or other woody fiber. In each case the test consisted not only of subjecting these floors to high temperatures, running from 1,700° to 2,100° or 2,200° F., but while they were at these high temperatures, to the effect of a fire stream for the period of fifteen or twenty minutes. The duration of each test from the time of starting the fire to the end of the application of the water was about five hours, although the highest temperatures existed for a period of one or two hours less. These fire-proof tests were conducted with the utmost care in order to make their conditions correspond as nearly as possible with the materials and quality of labor used in regular building constructure, and it is believed that the results were fairly representative of what may be expected in ordinary conflagrations.

After the cold fire streams had been thrown into the furnace and against the under side of the tested floors, a sufficient time was allowed for cooling and then careful examinations were made in order to ascertain in all respects the condition of the tested materials. A great variety and degree of results was naturally observed. I think it may be stated, however, that both concrete and hollow tile construction were found to be excellent fire-resisting materials. In certain quarters little faith has apparently been placed in the fire-resisting capacity of concrete made either with cinders or with stone or gravel. These tests conclusively demonstrate, if such a demonstration were needed, that the fire-resisting capacity of concrete is at least equal to that of the best hollow tile construction used at the present time. All the tested floors carried during their tests an extraneous load of 150 pounds per square foot, and practically all supported that load without undue deflection in view of the high tem-

peratures. After the furnace had cooled, the load of 150 pounds per square foot was increased to 600 pounds per square foot, and the greater load was generally supported in a satisfactory manner. Some of the plaster, both on wire netting and on other supports, frequently crumbled and generally fell off before the end of the test, particularly after the impact of the fire streams, which were thrown under a 60-pounds pressure. The under portions of the concrete in contact both with the high temperature and the cold water crumbled to a slight extent only, but on the other hand considerable portions of the lower surface of the hollow tile were destroyed, although generally without serious injury to the sustaining capacity of the floors as far as they were tested. In those cases where the concrete arches were formed over wire netting, the latter was found in general to stand well up to its duty. If any doubt existed in the minds of engineers and architects as to the fire-resisting capacity of concrete in floors, the results of these investigations should dissipate all such doubt. These experimetal results as to the fire-resisting capacity of concrete have been amply confirmed by the experiences of such fires as those in the Methodist Book Concern building at Pittsburg and in other actual conflagrations.

Another equally interesting and important series of fire tests is that which was begun in 1896 by a joint committee of the Tariff Association of New York, the Architectural League of New York and the American Society of Mechanical Engineers. That committee was intrusted with the testing of cast iron and steel columns under a high temperature, both without and with the application of fire streams. The committee has thus far been able to perform but a portion of its assigned duties. It has tested under the conditions described one steel box column composed of two 12 x ½ inch plates and two 10-inch channels riveted into the common closed form, the length of the column being 14 feet and its area of cross-section 15 square inches; 1 Z-bar column composed of four 4-inch Z-bars and one 6½-inch x $\frac{5}{16}$-inch plate, the length of the column being 14 feet 1 inch, and its area of cross-section 14·15 square inches; and three

hollow round cast iron columns, each 13 feet long, 8 inches in exterior diameter, with 1 inch thickness of metal, the area of the cross-section being 21·99 square inches. The first, or steel box column, carried a load of 96,120 pounds at a maximum temperature ranging from 1,200° to 1,250° F., at which the metal began to show red. At this maximum temperature its ultimate resistance was 6,408 pounds per square inch, whereas, at the normal temperature, it should have carried about 42,000 pounds per square inch. The thickness of metal of this column varied from $\frac{1}{4}$ to perhaps $\frac{1}{16}$ of an inch in the most exposed portions. The second, or steel Z-bar column, carried a load of 169,600 pounds at a maximum temperature ranging from 1,200° to 1,375° F., at which the metal showed red. The load sustained by the column per square inch was therefore 11,986 pounds, while its ultimate resistance at an ordinary temperature should have been about 39,800 pounds per square inch. The thickness of most exposed metal was practically $\frac{1}{16}$ of an inch. Both the preceding tests were without any application of water.

The first cast iron column tested carried a load of 169,600 pounds at a maximum temperature varying from 1,200° to 1,250° F., at which it showed slight redness. The ultimate resistance of the column at this high temperature was 7,713 pounds per square inch, while, at normal temperature, it should have carried 27,380 per square inch, as measured by the results of the tests of full-size cast iron columns at Phœnixville, Pa., and Watertown, Mass. This test was also without water. The fourth was a cast iron column test, and practically a repetition of the preceding in all respects, except that the maximum temperature reached 1,550° F. under the maximum load of 169,600 pounds, at which it was broken suddenly. The fifth and last test was of a cast iron column, practically identical with those used in the two preceding cases, and was a combination of high temperature with the application of a fire stream. The column was first raised to a temperature of 525° F., when water was thrown on it for one minute. The temperature was then raised to 1,000°, after which it was lowered to 400°, when

water was thrown on the column for one-half minute. The temperature was again raised to 1,050°, at which the column showed red, when water was again thrown on it for one-half minute. The temperature then fell below 750°, but was again raised to about 1,300°, when water was thrown on it for one minute, and immediately thereafter for two minutes. When the water was thrown on the metal the last time it was decidedly red. The column was badly bent, but not broken. The duration of these five tests varied from about thirty minutes to two hours and fifteen minutes each.

It appears from these investigations that the cast iron column at a temperature of from 1,200° to 1,300° carried a little less than one-quarter of its ultimate resistance at ordinary temperatures, while the steel columns in the one case carried practically the same proportion of its ultimate resistance at ordinary temperature, and a little more than one-seventh in the other case. When it is remembered, however, that the thickness of metal of the steel columns practically did not exceed $\frac{5}{16}$ of an inch, while the cast metal had a thickness of 1 inch, it may be fairly stated, I think, that, other things being equal, the efficiency of the steel column is at least as high as that of the cast iron in carrying loads at high temperatures, although it still remains for that conclusion to be either shaken or confirmed by further tests.

In these tests the steel and cast iron were exposed directly to the high temperatures, whereas numerous experiences in actual conflagrations have shown that when iron and steel columns and girders are feasibly protected against direct action of high temperatures, their carrying capacities are not often sensibly diminished.

A few isolated instances of late building construction indicate a line of development of no little interest and possibly of considerable importance. Reference is made to construction of the walls and partitions of buildings of combined concrete and wrought iron or steel. A few small buildings of this character have been built in California by the Ransome process, in which twisted square rods have been imbedded in the concrete in order to give tensile resistance. Pos-

sibly a beginning has been made in Chicago by the same process, while a building devoted to manufacturing purposes was constructed at Bayonne, N. J., last year. The combination of Portland cement, concrete and steel rods, netting or other light members yields a mass of great resisting capacity which, at the same time, lends itself readily to manifold structural demands. It may form the body of the wall with a brick, terra-cotta or stone exterior in any ornamental design, or, in many cases, as in those named, it may constitute the entire wall. We are but just beginning to realize what a valuable structural material we have in concrete, particularly when it acquires considerable capacity for tensile resistance by the introduction of light steel reinforcement, as in the Ransome method and in the Melan, Monier and other systems of arch construction. With the excellent domestic Portland cements now available at economic rates, and with such advances as that exemplified by the production of silica—Portland cement—no less than by our knowledge of improved methods of concrete making, the field of application of concrete construction is widening rapidly. It is quite possible that the extending limits of that field may soon include monolithic-steel building, characterized by both economy and endurance. The materials are admirably adapted to such an end, certainly at all usual temperatures, since their rates of thermal expansion and contraction are practically identical. New problems of construction of more or less difficulty will undoubtedly arise, but if there should ever be a demand for their solution they will certainly be solved.

DISCUSSION.

WM. COPELAND FURBER:—Professor Burr's comprehensive discussion of this subject leaves but little to be said. His ideas, as set forth here to-night, endorse the best modern practice, regarding which there should be but little room for differences of opinion; but notwithstanding our knowledge of design there seems to be a lack of care or knowledge in the preservation of the iron skeleton from corrosion.

On the question of rust protection I may be taking

advanced ground I say I believe that entirely too little attention has been paid to this matter by designers; yet the liability of corrosion is so great through exposure and improper covering and the lack of preparation of the metal to receive and hold the covering that I think the use of the sand-blast or some equally efficient means to remove the mill scale and permit the direct application of the protective covering to the actual surface of the metal is not only justifiable but imperative. When the skeleton is once enclosed examination is difficult, and repair practically impossible; and as the life of the building is coincident with the life of the framework, and the value of the investment is determined primarily by the integrity of the finished structure, a short-sighted and temporarily apparent economy should not be allowed to curtail a proper expenditure on the skeleton, which if intelligently made, will assure the building a practically indefinite existence.

As to the best means of providing against rust, the information already at our disposal seems to me sufficient to indicate a safe course to pursue. Ledebur, in his handbook, pp. 277–281, in an "Essay on Oxidation of Iron and its Admixtures, Rusting and the Influence of Liquids upon Iron," points out that three factors are required to produce rust—that is, the hydrated oxide, viz.: water, pure oxygen and an acid. Portland cement by furnishing a base for the absorption of any acid likely to be found, will eliminate one of these factors, and will thereby prevent rust. So that with the other valuable qualities it possesses it forms a protective covering of great value. But while this is true if the cement is in direct contact with the metal, we know that as the shapes come from the shops they are covered with mill scale, and that any covering applied to them adheres to the scale, and that a mechanical separation of the scale is easily possible.

Should water penetrate the cement or other covering, through cracks, and find its way between the scale and the actual surface of the metal, the scale being electro-negative to the body of the metal, the elements of a battery exist, and the degree of corrosion is a matter of time.

We also know that as concrete is frequently put in place the voids are not filled up and spaces are left for the accumulation of water, which may be present, forming with the scale already there, rust-producing factors.

It is not an uncommon thing where iron footings are placed below the water level to find that the water has dissolved and washed out all the cement which the concrete originally contained. I have seen more than one building standing with its "feet" wet, the cement having been washed out before the concrete set, leaving but the stone and sand remaining.

I believe, and have followed it out in my own practice, in placing all iron above the line of saturation if at all possible, and in the Harrison Building, which has been referred to here to-night, and for which I was the designing engineer, the grillage of I-beams in the footings is above the water level, the foundations below this being entirely of concrete; but when, for any reason, the grillage or underground metal work has to be placed below the water level, most extraordinary care should be used to see that the metal work is free from scale and unpainted, that the trenches or pits are so lined that no part of the excavation comes in contact with the beams, that the concrete contains a large proportion of cement with the aggregate or "filler" in small particles, so as to allow being rammed easily into a dense mass without voids. In the placing of long girders underground it is not an uncommon thing to see the earth fall in around the girders, and to see the concrete filled in without the earth being removed. It is needless, perhaps, to say that whenever this occurs a "fault" is formed in the concrete, and rust must inevitably follow.

On the structural work above ground the danger of corrosion is not so great, but is sufficient, I think, to warrant the use of a concrete envelope around the columns and external girders, for the masonry covering is not always thick enough or tight enough to exclude moisture. If concrete is used, the metal work should be temporarily protected by a coat of oil, which will be worn away by the time the building is ready for closing in.

Regarding column sections much remains to be said, and the selection of a closed or open section is, I think, an open question. The closed section is undoubtedly the better, both economically and structurally, but the difficulty of protecting the metal from corrosion is greater.

I have seen instances where the closed section held the rain collected during erection, which, with the drillings, cuttings and débris, which also found ready lodgment therein, supplied the elements for rust. A very interesting discussion on the subject of rust-prevention can be found in the Proceedings of the Engineers' Club of Philadelphia, Vol. XII, p. 225.

Wind-bracing is given by Professor Burr the attention its importance deserves, and, in view of the possibility of the accurate determination of the stress caused by an assumed wind pressure, it seems shortsighted and unwise to neglect provision for it in proportioning the structure. Outside of the increased stability and permanency it gives the building, it has the great merit of facilitating the erection, by permitting the columns to be retained in their correct vertical position, and in high buildings this is a matter of considerable difficulty.

Wind-bracing is frequently omitted because the architectural treatment adopted does not permit its use, and for this reason existing there is little justification. A rational and intelligent architectural designer can fit the architecture to the requirements of proper engineering design, and his failure to do so is a reflection on his knowledge and ability. Architectural traditions call for the exercise of few qualities beyond an academic conservatism, but the modern development of structural design has been carried forward without precedents, and its growth should not be restrained because the old architectural clothes will not fit it. The architectural treatment should follow the structural design, not prescribe it.

The fire-proofing of the metal frame work has not yet been brought to perfection, and the method of applying the various coverings now in use leaves much to be desired.

The high fire resistance possessed by Portland cement,

makes it an excellent fire-protecting material, and I believe, if properly applied, answers all the purposes of fire-proofing and rust prevention.

Portland cement, combined with a wire mesh to give it fibrous properties, is practically indestructible under the conditions likely to be encountered in a strictly local fire, and for column and girder coverings is the best material I know of, but the ease of its application makes it particularly liable to suffer from the evils of poor workmanship, and the most rigid inspection is required in mixing and applying it to secure the desired results.

For floors, I believe the porous terra-cotta tile with ample covering on the flanges of the beams is the best practical sort of a floor. In this the evil of poor workmanship is reduced to a minimum, and with any sort of efficient inspection poor results can be guarded against; whereas, with a concrete floor, a poor batch of concrete may lead to unpleasant results. The necessity also for using an aggregate or "filler" in the concrete, of a material like ashes, for lightness, is an objection of some importance.

The protection against fire by a comprehensive system of water-piping, arranged so as to distribute a sheet of water over exposed walls, has received little attention so far; with such a system protected against freezing on external exposures, and an efficient pumping plant, I am sure the Home Insurance Building, in New York City, could have been protected from serious loss. The Harrison Building, in this city, shows an attempt made in this direction.

When the problem of large building design is looked at from an economic standpoint, and the co-relation of the tenant and owner is considered, the solution of the question of providing the necessary facilities for office room, and the distribution of light, heat, ventilation, water-supply and elevator service for the comfort and convenience of the hundreds of tenants, with the greatest efficiency, becomes an engineering problem of great importance. And as the extent and permanency of the investment as a continuous interest-earning proposition depends upon the best solution of engineering features, structural and mechanical, the

whole matter is raised above that of mere architectural expediency to one of public policy.

A too great, insufficient or unwise expenditure reacts on the owner and tenant, finally on the community, to the detriment of each.

In conclusion, I would say that I believe that the highest results will not be realized until the engineer is recognized and granted his place in the primary design of the building, and the architectural treatment is co-ordinated to its rightful place.

Mechanical and Engineering Section.

Stated Meeting, held Wednesday, March 9, 1899.

MECHANICAL APPLICATIONS OF COMPRESSED AIR.

(Abstract of remarks by Mr. W. L. SAUNDERS, M. Am. Soc., C.E., Member of the Institute, in opening the discussion.)

MR. SAUNDERS:—I fear that your Secretary is treading upon dangerous ground when he puts me on tap so early in these proceedings. I once heard the question asked, what is the difference between electricity and compressed air? The answer was given in this way: They are both things that we know very little about, and the men who think they know most about them are the ones who make the greatest number of mistakes in talking too much about them; but there is one difference between them which everybody understands: An army of men may be killed one after the other by touching a live electric wire, while with compressed air, when the bottle once explodes, it dies in the attempt.

This is a very broad subject. Though one of the oldest of the sciences, compressed air in its practical application is one of the youngest. It is my purpose to touch but generally upon this subject, more in the line of an introduction than otherwise, but I shall have to ask your pardon when I go back more than a century before Christ and do honor to

our first pneumatic author and inventor, Hero, of Alexandria. Hero's fountain is but a jet of water sustained by compressed air. He describes in his work on pneumatics a pump or fire engine, in which the elasticity of air was an important feature. Hero also describes an invention of Ctesibius, consisting of a tube out of which an arrow was shot by means of compressed air—an early suggestion of the dynamite gun. This philosopher is said to have put into practical operation an invention by which the opening and closing of temple doors was effected by the alternate expansion and contraction of air when brought in contact with heated and cooled surfaces of altar tops.

We may now pass over centuries of the world's history, coming down well into the sixteenth century without finding any important practical applications of compressed air. The diving bell, so useful in building foundations for bridges, was perhaps the first really important use of compressed air; but with the exception of a few obscure instances we must get well into the nineteenth century in order to find compressed air generally used in caisson work. Beginning with the work of Rennie, in 1812, we have the records of Cubitt, on the Rochester Bridge, England, and Brunel in the Thames Tunnel. From bridge and tunnel construction, compressed air was extended in usefulness to mines and quarries, next to railroads, foundries, machine shops, acid factories, steel works, lifting and purifying water, and in numerous other useful applications of less importance.

Let us stop to consider how important some of these applications are. It is difficult to conceive the possibility of extensive bridge construction without the use of compressed air, and need we stop even for a moment to question how far in this respect alone compressed air has aided in the world's progress. The construction of great tunnels has been made possible by compressed air. This line of usefulness is not confined to railway tunnels, but to aqueducts and mines. The building of the New York Aqueduct, 30 miles in length through solid rock in three years is a recent example of the usefulness of compressed air. It is not an

uncommon record for a tunnel to be built by compressed air machinery in one-third the time and at one-half the cost when compared with hand labor. This means that in mines ores of low grade which otherwise might not pay, are made useful to the world. Think, for a moment, how much compressed air may have aided in the wealth of nations by increasing the production of the precious metals!

The largest application of compressed air is in connection with railroads. We may say with safety that air is supreme as a brake. More than 30,000 locomotives are equipped with air brakes, and it is doubtful if there is anything since the invention of the locomotive which has been of such importance to railroads as the air brake. It has not only increased facilities for transportation, but it has saved thousands of human lives.

Later on we will refer to other useful applications of compressed air in railway service, but here let us stop to give proper place in importance to the use of air in making steel. This has been called a "revolutionary use of compressed air," and by some it is considered its most important application. The Bessemer convertor uses air under pressure and forced through a mass of melted iron to burn out the carbon and thus convert cast iron into steel, making it possible to produce steel at a lower cost than iron. The enormous increase in the use of steel for rails and structural work generally may be laid to the Bessemer process.

Compressed air can be produced best and cheapest by the use of compound, condensing steam engines driving air pistons which compress the air in stages, intercooling between each stage. The rules which govern steam economy generally apply with equal force to the Air Compressor, and it is just as important to use compound air cylinders as it is to use compound steam cylinders. Air may be compressed to any practical pressure. Our experience with it is usually at pressures under 100 pounds per square inch, except in storage service, where it is used at 2,500 pounds per square inch. It is just as easy to compress air to higher as to lower pressures, it being simply a question of proper design of machine, but the higher the pressure the greater

should be the number of stages of compression, and the greater the importance of intercooling between stages.

Air transmission offers few if any difficulties except where it is desired to transmit large volumes great distances, and the trouble in such a case is only that the cost of the conduit makes the installation prohibitive from a commercial standpoint. Long distance electric transmission has been made to pay only when the current is transmitted at high voltage, and the same rules govern compressed air; it is

FIG. 1.—Car wheel and axle hoist.

best to transmit it at high pressures because we get a larger volume in proportion to the diameter of the conduit. At the present time our experience with pipes carrying compressed air at high pressures is so limited that long distance air transmission at high pressures must be said to be still in the experimental stage. The experiments, however, apply almost entirely to the mechanical construction of the conduit. We need pipes built for the purpose, and joints of proper construction to prevent leakage. It is a popular error, however, to suppose that there are any large losses

suffered in compressed air transmission. In practice, the losses suffered by transmission are so low that they are not taken into consideration. This is, of course, mainly due to the fact that the pipes are properly proportioned, and the distances traversed are not great.

To return to the practical applications of compressed air.

Air Brakes.—The best known type is that of the Westinghouse, where the air is compressed at the locomotive and conveyed to storage tanks on the cars. For street car service, air is compressed on the car by means of a small electric motor, operated through the axle. Another system has recently been introduced at Detroit in which no compressor is used on the car, but the air is stored at high pressure and is used through reducing valves to release the brakes.

Air Hoists.—These hoists are commonly used in railway yards and shops, foundries and machine works. The illustration herewith shows the hoist applied in a railway yard for lifting car wheels. These hoists are divided into two classes, the direct and indirect lift. The most popular type is the direct lift, and consists mainly of a cylinder or pipe in which is inserted a piston, the rod of which is attached directly to the weight to be lifted, compressed air is used directly upon the piston. The other form of hoist is shown in *Fig. 2.* By means of a little engine a pinion is turned in a lifting block and the load lifted by the differential pulley method.

Various modifications of these hoists are in use. In some cases the cylinder is placed in a horizontal position and the load lifted through a rope connected to the piston rod and passing over one or more pulleys. These hoists are of especial advantage, because of their simplicity, quickness of action and availability. They are usually applied to light loads under 1 ton. Other forms of air hoists are shown in the accompanying illustrations.

Pumping Water by Air.—Two systems are in use, a direct application of compressed air to liquids in wells, commonly called the Pohlé system, and the displacement pump system. The two have distinct applications: the first is a well pump, requiring deep submergence, and the second is a means by

which one or more vessels filled with liquid are submerged in the liquid to be raised, and compressed air is applied to the surface of the liquid in the vessel, forcing it to any desired point. The displacement pump system is used in sumps and for raising acids.

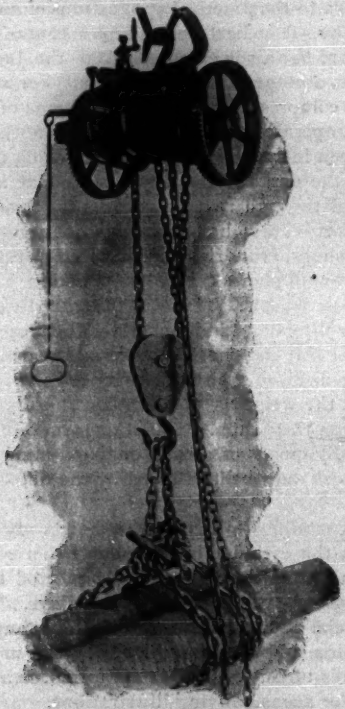


FIG. 2.—Pneumatic motor hoist.

The air-lift system for wells, consists of an air compressor, an air receiver to equalize the flow of air to the well and the piping in the well. The compressor is located in the engine room, where it is always under the eyes of the

FIG. 3.—Car-wheel hoist.

FIG. 5.—Car-lifting jack.

engineer, and as compressed air can be conveyed a considerable distance without loss, the well may be far away. The method of piping a well differs, according to its general conditions and the quantity of water to be pumped. No two wells are alike, and, consequently, the method of piping,

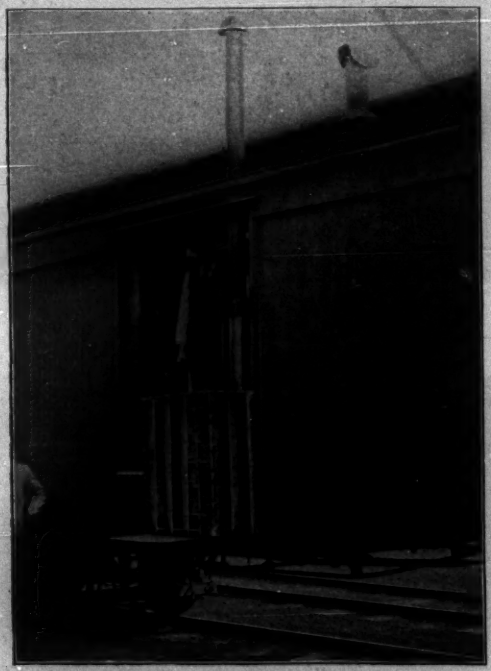


FIG. 4.—Baggage hoist.

which might be applied to one, would be unsuited to another.

In the accompanying illustration the method of piping consists of using the well casing as the water discharge pipe and simply putting a small air pipe down in the well,

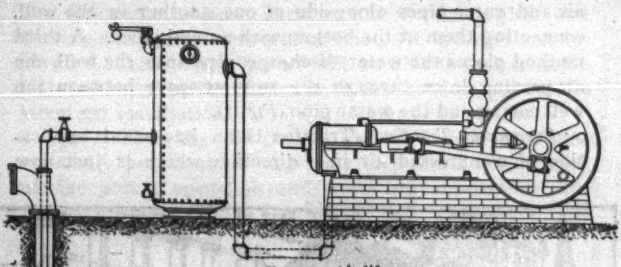


FIG. 7.—Air lift-pump.

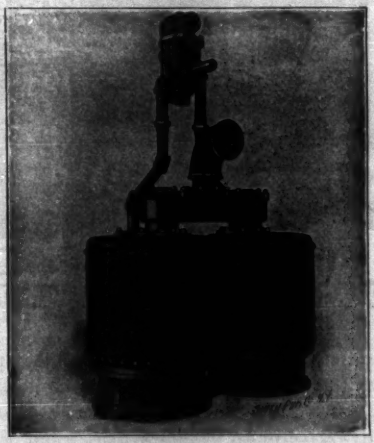


FIG. 6.—Displacement pump.

with a special device attached at the bottom through which the air escapes. Another method consists of placing the air and water pipes alongside of one another in the well, connecting them at the bottom with an end piece. A third method places the water discharge pipe into the well, the air passing down through the annular space between the well casing and the water pipe (*Fig. 7*).

Pneumatic Traction.—Traction is an important application of compressed air in a direction which is just now

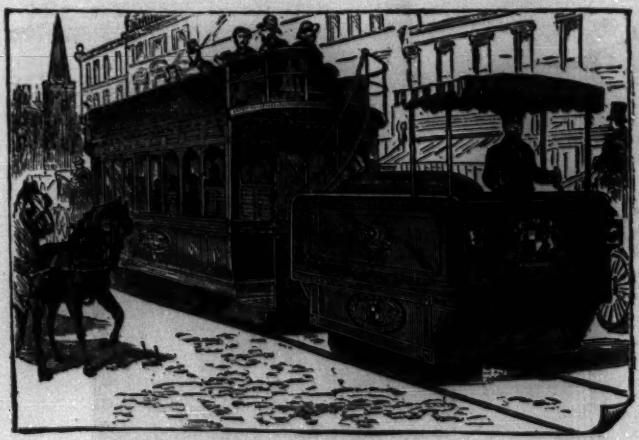


FIG. 8.—Trial of the Beaumont compressed-air motor at Woolwich Arsenal, England.

very promising. It is too broad a subject to be discussed in detail here, but I illustrate in the following the several prominent systems which have been put into practical operation. *Figs. 8* to *12*, inclusive.

In connection with this subject I can do justice to pneumatic traction in no better way than to attach herewith a reliable paper written by Mr. Edward E. Pettee, on the cost of operating the Hardie cars in New York City. The Hoadley-Knight system, which is in many respects similar

to the Hardie, and perhaps an improvement on it, is now being installed under the auspices of the Metropolitan Traction Company in New York on the Twenty-eighth and Twenty-ninth streets cross-town lines. It is hoped and believed that one year hence we will be able to present some facts of value in connection with this modern pneumatic street car installation.

Cost of Operating Air Cars in New York City.—It seems especially pertinent at this time to publish a statement of the actual operation and operating expenses of the American Air Power Company's cars that have per-

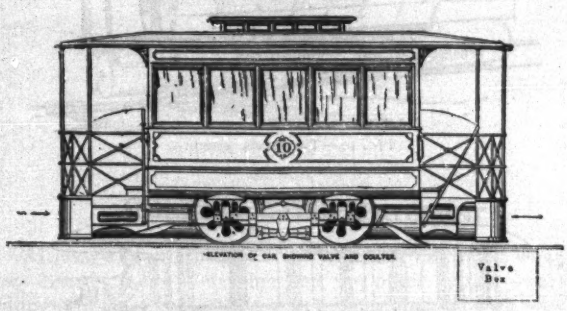


FIG. 9.—The Hughes and Lancaster system.

formed a regular commercial service on the One-hundred-and-twenty-fifth Street line of the Third Avenue R. R. in New York City, since the 3d of August, 1896, with a success unparalleled in the history of mechanical traction.

The period elapsed covers the extreme ranges of temperature experienced in this locality, and fortunately also two snow storms of more than ordinary severity, so that the seven months' continuous duty on which the following statement is based will meet the conditions incident to any street railway service.

The One-hundred-and-twenty-fifth Street line of the Third Avenue Railroad extends across town from the North River

to the Harlem River, the length of the tracks being 10,854 feet, making the round trip 4·11 miles, over which cable cars are operated at intervals of two and a half minutes. Air cars were substituted for two of these cable cars, the schedule calling for nineteen round trips each, or 79·09

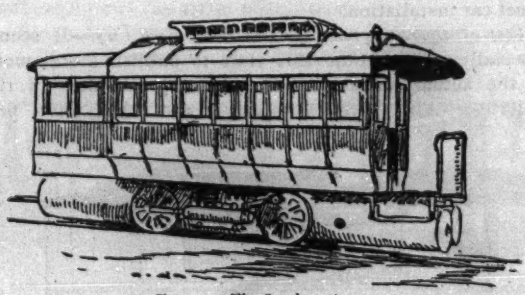


FIG. 10.—The Jarvis system.

FIG. 11.—The Mekarski system at Toledo, O.

miles per car; for a daily service of 156·18 miles, besides 1·14 miles of switching to and from the car house and street tracks, making the total distance covered daily 157·32 miles. Each car runs from 12·50 to 16·67 miles on a single charge of air.

The switching referred to is unavoidable in operating this service owing to the arrangement of the car-house in relation to the street tracks, it being some distance from the terminal of the road.

During a portion of the time, only single service was performed, as at present, so that the total average mileage per day from August 3d to March 3d, was 125·16 miles, and the total distance covered, 23,030·5 miles; and the total number of passengers carried, 137,386. The cars have operated every week-day, but are not run Sundays.

[*To be continued.*]

ELECTRICAL SECTION.

Stated Meeting, May 23, 1899.

A NEW PRIMARY BATTERY.

(THE HARRISON CELL.)

By J. D. Darling.

Although it was in 1793 that Volta discovered that when two discs of metal—one zinc and the other copper—were brought in close contact the zinc became charged with positive and the copper with negative electricity, it was not until 1799 that he constructed his famous primary cell, and it is now proposed to hold an exhibition at Como, Italy, his birthplace, from May to November of the present year, to celebrate the discovery a century ago of chemical electricity.

Few discoveries are more deserving of commemoration, as, previous to his discovery, the static machine was the only source of electricity the investigator had at his command. Volta's cell furnished the first practical source of electrical energy, and in a form that enabled experiments to be made which culminated in that of Faraday—the base of all our present electrical development.

I now wish to call your attention to the latest form of voltaic cell, which has been brought to perfection during

this centennial year, and in which it has been aimed to embody as many as possible of the desirable qualities that the experience of the past 100 years has shown to be necessary in a good voltaic cell. Ever since Volta pointed the way, efforts have been made to devise a perfect form of voltaic cell, but so far unsuccessfully; galvanic polarization and local action are the principal difficulties that beset the path of the inventor of primary cells.

As I will have occasion to refer repeatedly to polarization and local action in describing how these difficulties were overcome in the cell under consideration, I will here give the definition of these two terms as given by Park Benjamin.

"Polarization is a condition due to the formation of a body, most commonly hydrogen, by electro-chemical decomposition upon the negative electrode, whereby a current in opposite direction to the normal current of a cell is produced, and through which the normal current may be greatly weakened."

"Local action is chemical action occurring within the cell, and is caused by the innumerable small currents which circulate between portions of the same electrode."

A great variety of chemical substances have been used as depolarizers, and even mechanical devices to utilize the oxygen of the atmosphere have been tried. The substances have usually been such as will readily give up oxygen to combine with the hydrogen to form water, and may be either liquids or solids. An objection to liquid depolarizers, besides that of having two liquids in the same cell with the accompanying porous cup or other device to keep them separated, is that but a small percentage of the total depolarizer present in the cell is available for useful work, as there is generally a large amount of chemical energy left in the solution after it is too weak for satisfactory work.

Solid depolarizers are preferable to liquid ones, for with solid depolarizers one liquid only is required in the cell, and porous cups can be dispensed with, and the efficiency, or amount available for useful work, is also higher than is the case with liquid depolarizers.

The following table gives the E.M.F. of various cells in which a few of the most commonly used depolarizers—liquid and solid—are used, zinc being the positive element in each case:

Liquid Depolarizers.	Name of Cell.	Volts.
Copper Sulphate,	Daniel,	1·079
Potassium Chlorate,	Salleron-Renoux,	1·600
Nitric Acid,	Bunsen,	1·900
Potassium-Bichromate,	Poggendorff,	2·140
Cupric Oxide,	Lalande-Chaperon,	0·98
Silver Chloride,	De la Rue,	1·03
Manganese Peroxide,	Leclanche,	1·40
Mercurous Sulphate,	Mari-Davey,	1·412
Lead Peroxide,	Harrison,	2·45

It is evident that the cell in which lead peroxide is the depolarizer has by far the highest E.M.F. This new cell, known as the "Harrison" Primary Cell, No. 1, is the cell that I propose to describe in this paper. It is an open circuit primary cell, having a positive element of amalgamated zinc and a negative element of hard lead surrounded by a mass of specially prepared lead peroxide (PbO_2). The electrolyte is dilute sulphuric acid, 1 part of acid to 6 parts of water. The E.M.F. of the cell is 2·40 — 2·50 volts, the average being 2·45. The internal resistance averages ·15 ohm, therefore on short circuit the current is about 16 ampères. The negative element is in the form of a round stick, about 4 inches long by $1\frac{1}{8}$ inches in diameter. It is made by compressing in a special machine a mass of lead peroxide around a central conductor of hard lead that has previously been treated in a way that prevents sulphating. This conductor is provided at one end with a copper screw that passes through the cover of the jar and is held in place by a binding post.

It is not claimed that the use of the lead peroxide for the negative element in this cell is new, for Benjamin says in his book, "The Voltaic Cell," page 228: "In 1843 Wheatstone observed that by covering the negative electrode of a cell with a body of peroxide of lead or peroxide of manganese the E.M.F. of a cell could be greatly augmented. De la Rue reached the same conclusion at about the same period." Since then numerous inventors have tried to make a

practical cell, using lead peroxide surrounding a conductor as a negative element, but the difficulty of making a peroxide that would hold together, and not disintegrate when used, has never been overcome until recently.

This seemingly insurmountable difficulty has been practically overcome in the Harrison cell after several years of experimenting. Every kind of binding material that offered any hope of success was tried, and failed, and even coating the sticks after they were made with different cements was tried, and failed. Several times it was thought that success had been achieved, as occasionally sticks would last for

FIG. 1.—Harrison cell, No. 1.

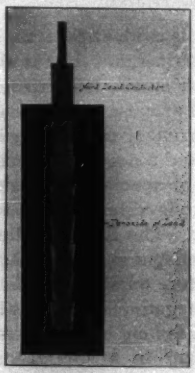


FIG. 2.—Negative element of No. 1 cell.

months without cracking or falling to pieces. Success was ultimately attained only after the trouble had been traced to its source, and special means and processes devised to prevent it.

The process of manufacture is now as follows:

The lead peroxide is prepared electrolytically, and when finished is almost chemically pure PbO_2. Certain precautions have to be observed to insure success. The neglect of any one of them gives us a peroxide that, when made into a stick, will crumble to pieces when put into the elec-

trolyte. The proper amount of finished peroxide is then compressed around the conductor in a very ingenious machine, especially designed for the purpose, and which is worked by compressed air. The finished sticks are allowed to dry for a week or more before being made up; they are then extremely hard, and stand handling and shipment very well.

I will now proceed to describe the positive element of the cell, which also possesses some new features. At first glance it appears to be only a short rod of zinc, 1⅛ inches long by 1 inch in diameter, with a short conducting copper wire attached to it, but, as dilute sulphuric acid is the electrolyte used in the cell, it is plain that zinc alone would not last long, and a closer examination will show that means have been taken to keep it amalgamated. It is well known that if the zinc element in a primary cell is kept well amalgamated there is little or no local action. Kemp, of Edinburgh, was the first to point this out, in 1828, and although it would appear to be a simple matter to keep the zinc amalgamated, in reality it is not, for on account of the high specific gravity of mercury it has a constant tendency to separate from the zinc, thus leaving the zinc open to attack by the acid. To overcome this tendency the zinc element in the Harrison cell is cast in the form of a cup, and has a stout copper wire, threaded at one end for attaching the binding post embedded in it. In this zinc cup and around the copper wire enough melted zinc amalgam is poured to completely fill it. This amalgam, when cold, is perfectly solid, and no free mercury is visible. This is a most valuable feature, as there is no mercury to spill and be lost when shipping the cell. Yet it is not necessary to amalgamate the zinc when setting up the cell, as

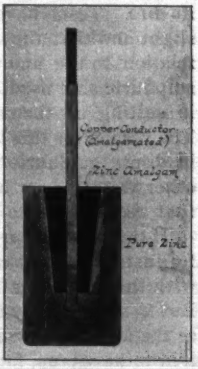


FIG. 3.—Positive element of No. 1 cell.

the mercury that is in the element in the form of solid zinc amalgam is almost instantly available when it comes in contact with the exciting fluid.

What occurs when the cell is set up is as follows: Zinc amalgam is electro-positive to pure zinc, the difference in potential being 0·05 volt; therefore, when the zinc element I have described is placed in dilute acid, the first action takes place on the surface of the zinc amalgam. The zinc of the amalgam is dissolved and a minute quantity of the mercury is liberated; this in a very short time spreads itself over the surface of the element and, as there is then nothing but zinc amalgam exposed to the acid, all action ceases.

The zinc element in the Harrison cell is, therefore, self-amalgamating, for it retains this property of liberating just the necessary amount of mercury needed to the end of its life. Tests have shown that the local action is very slight and that the amount of zinc dissolved bears a close relation to the amount of energy obtained, providing the sulphuric acid used is pure. If impure acid has been used in setting up the cell, local action will occur on the zinc. The reason for this is that the zinc is highly electro-positive in dilute sulphuric acid and will precipitate on itself all other metals lower in the electrolytic scale, or less positive, that may happen to be in the acid used in setting up the cell.

If the metals so precipitated readily amalgamate—copper, for instance—no harm will ensue, for they will combine with the amalgamated zinc and no local pair will be formed. But if, as is usually the case, the metallic impurities present in the acid are arsenic, selenium or iron, local action is certain to be set up, for they will be precipitated on the zinc and, as under the conditions they will not amalgamate, a multitude of local pairs are formed on the surface of the zinc element and it is rapidly consumed.

As sulphuric acid manufactured from iron or copper pyrites always contains more or less arsenic and selenium, such acid should never be used in the Harrison cell except the following precautions are strictly observed. If there is a doubt about the purity of the acid, proceed as follows: set up the cell as per directions and allow it to stand for

forty-eight hours. If the acid is not pure, local action will have been set up on the zinc and gas bubbles will be seen to be rising steadily instead of adhering to the zinc. To stop the action and prevent its return, take the zinc out and scrub it off thoroughly with a stiff brush in running water. This treatment will remove the precipitated impurities from the surface of the zinc that were causing the trouble, and as there are no more left in the solution, the zinc can be replaced again and there will be no further local action.

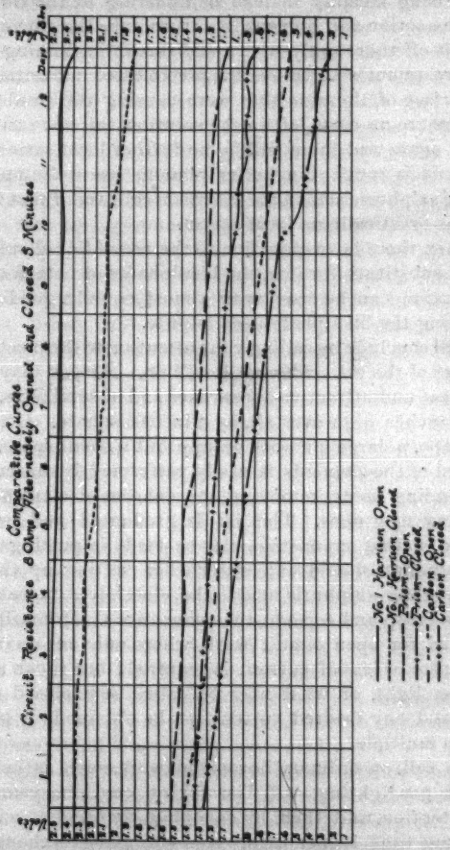
But it is much the better plan to use only pure 66° Baumé sulphuric acid in the Harrison cell, and if that is done there is practically no local action.

When there is an objection to the use of liquid sulphuric acid, a substitute for it in the bisulphates of potash or soda in solution can be used with almost equally good effect, providing the bisulphate used is pure.

I will conclude by calling your attention to the mechanical features of the cell and what it will do. As you may see, it is of neat and attractive appearance and of small size, being only 6 inches high over all, by 3 inches square. Owing to its shape, a large number occupy but a small space. The renewal of the elements is easily performed by unscrewing the binding posts, removing the exhausted elements and inserting new ones. The jar is graduated and properly marked so that no mistake can be made in putting in the right amount of acid and water when setting up the cell, and as dilute sulphuric acid is the electrolyte there are no salts to creep and corrode the connections. Primarily it is intended for open circuit work, where only one-quarter of an ampère or less of current is required; but it can also be used on light, or what may be called semi-closed circuit work, and any desired current can be obtained by putting cells in multiple.

The cell, on ordinary household work, such as bell-ringing or gas-lighting, will last for at least one year without attention, and then, by changing the acid, it will last for some time longer before it is necessary to change the peroxide stick for a new one. The zinc generally lasts as long as two peroxide sticks, but, of course, the life of the

cell depends upon the amount of work it is called upon to do. If, through defective wiring or any other cause, it is



short-circuited, or, as it is called, "grounded," its life will be shortened, as would be the case with any other primary cell.

The curves herewith shown were obtained by putting on the same resistance a Harrison cell and two of the ordinary sal-ammoniac cells, one having peroxide of manganese for a depolarizer and the other being a plain carbon cell. The circuits had each a resistance of 8 ohms, and they were opened and closed every five minutes by clockwork for twelve days of eight hours each. At the beginning of tests the E.M.F. on open circuit of each cell was: Harrison, 2·5 volts; sal-ammoniac cell (depolarizing), 1·5 volts; plain carbon cell, 1·4 volts. At the finish the E.M.F. on closed circuit was: Harrison cell, 1·8 volts; sal-ammoniac (depolarizing), ·8 volt; plain carbon cell, ·2 volt. This shows that the Harrison cell had at the finish of the test a higher E.M.F. on closed circuit than the best of the sal-ammoniac cells had at the beginning on open circuit by ·3 volt, and it should not be forgotten that the current from the Harrison cell had been at least double that of the other cells during the test.

I would now call your attention to another form of cell—what is known as the "Harrison Cell, No. 3." This cell has also lead peroxide and amalgamated zinc for its elements. It has been especially designed for heavy closed-circuit work. Its E.M.F., when new, is 2·7 volts, and its life is 300 ampère hours, on a slow rate of discharge.

In this cell the negative conductor is outside the peroxide of lead, and is in the shape of a perforated basket or grid, divided internally into four equal spaces by lateral walls, and supported by a central rod passing through the cover of the jar and forming the positive terminal of the cell. By this form of construction a large negative surface in close contact with the depolarizer is obtained. The entire element is of a very solid and substantial construction that is not easily injured in shipping, and, when exhausted, can be recharged and used over and over again.

The positive element is granulated zinc, lying on a copper grid on the bottom of the jar that has an insulated copper conductor passing up through the cover to form the negative terminal of the cell. To prevent local action, a quantity of mercury is placed in the bottom of the jar, which serves to keep the zinc constantly amalgamated.

Three advantages are secured by using granulated zinc. One is that because of the large surface of zinc exposed in close proximity to the negative element, the cell has a very low internal resistance and a consequently high ampèrage. Another is the ease with which the zinc can be replenished; and, thirdly, the economy obtained in the consumption of zinc. All the zinc put into the cell is used. There are no pieces left to be thrown on the scrap heap, as is the case with cells having vertical plates of zinc. Of course, there is the same need in this cell as in the No. 1 to use pure sulphuric acid, or a solution of pure bisulphate, and the same

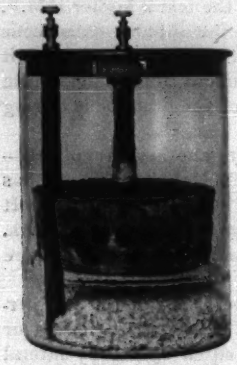


FIG. 5.—Harrison cell, No. 3.

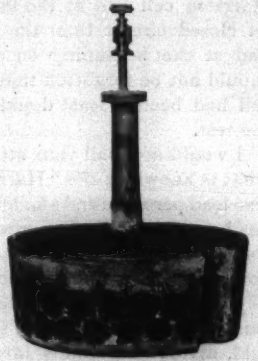


FIG. 6.—Negative elemept of No. 3 cell.

directions apply for stopping local action caused by using impure acid.

Its high E.M.F., large current, freedom from local action and the ease with which renewals can be made give this new cell distinct advantages over all other forms of what are known as closed-circuit cells. It takes a battery of three copper oxide cells coupled in series to give the voltage of one No. 3 Harrison cell. Manufacturers and users of gas and gasoline engines have long felt the need of a high-voltage primary cell to operate the spark coil attached to their

engines, and I believe they will find what they have been looking for in this new cell. Physicians and dentists will also find it well adapted to their needs, and it can be used for operating coils in X-ray work, for telephones and phonographs, as well as for running small motors and fans.

Where small storage batteries are now used this new cell will be found more convenient, for, besides having a higher E.M.F., there is not the need to send away the whole cell to have it recharged; with an extra negative element and a supply of acid and zinc, the cell can be kept running continuously with but little trouble; or, if desired, and a current is at hand, it can be used as a secondary cell.

CHEMICAL SECTION.

Stated Meeting, held December 6, 1898.

REACTION VELOCITY.

By Dr. Robt. Hart Bradbury,
Member of the Institute.

(*Concluded from vol. cxlvii, p. 474.*)

In closing this brief exposition of the formulary side of our subject, it is interesting to note the extreme simplicity of the mechanism of chemical changes. Trimolecular reactions are extremely uncommon and reactions of a higher order than three are unknown at present. Now, the pages of every text-book bristle with reactions which, in terms of the molecular theory, require the meeting of many molecules. Take, for instance, the familiar

$$3Sb_2S_3 + 28HNO_3 = 3Sb_2O_5 + 9H_2SO_4 + 28NO + 5H_2O.$$

Undoubtedly such expressions describe correctly the quantitative transformations which have taken place, but as regards the mechanism of the change itself, the impression they produce is utterly false. For the present, it seems best to consider that the chemical equation describes the

result of a complex of changes which have occurred consecutively. For instance, in the decomposition of arsine,

$$4AsH_3 = As_4 + 6H_2,$$

the first event is simply

$$AsH_3 = As + 3H,$$

after which the arsenic and the hydrogen atoms are at once grouped into molecules As_4 and H_2.

We next proceed to consider disturbing influences which affect the course of a reaction and prevent the law of mass-action from finding clear expression.

The progress of chemical changes is profoundly affected by a great variety of circumstances which we should be inclined to regard, *a priori*, as entirely indifferent. In the case of gases, the character of the vessel walls; in the case of liquids, the solvent; in all cases the presence of various substances, which take no part in the change, are conditions which have enormous effect on the speed of transformation.

Starting with the simpler physical transformations, we may consider first the case of an evaporating liquid. Here the final state of things for any temperature is, neglecting gravity, a uniform vapor phase in equilibrium with the liquid. This requires an actual transportation of the substance through space, which is slowly brought about by diffusion.*

If a special structure, *e. g.*, a crystal, results from the change, production of this structure will require time, and this will influence the speed of transformation. In the melting of a solid, the liquid which results is structureless; hence, the velocity of change is simply proportional to the heat supply, and it is impossible to heat a solid above its melting-point.

In the reverse change, the solidification of the liquid, the product is crystalline, and the arrangement requires time

* Van't Hoff, "Vorlesungen," p. 202. His discussion of catalytic action and allied topics is excellent, and I am indebted to it for several facts and suggestions.

to progress and, more especially, unless some of the same solid phase is added, time to begin.

Hence the phenomena of supersaturation and supercooling.

The influence of the vessel walls is most marked in the cases of gases, because the proportion of exposed surface to the total mass of the system is immensely greater than in liquid systems, and because of the greater rapidity of diffusion. The classical researches of V. Meyer, Krause and Askenasy in this field have failed to reveal anything beyond the magnitude of the influence and the perfect irregularity of the phenomena. The particular change investigated was the combination of hydrogen and oxygen. The stochiometric quantities were exposed to constant temperatures in small glass spheres. In different spheres of the same size, prepared in the same way and exposed to the same temperature, the speed of change is enormously different. The action of the hot-water vapor upon the glass changes the character of the surface, and this exerts an influence upon the transformation, which is sometimes accelerating and sometimes retarding. Etching the interior surface of the spheres by means of hydrofluoric acid yielded similar results. The speed of change was greatly increased by coating the interior of the spheres with silver, copper, platinum or palladium, but different spheres coated as nearly as possible in the same way, gave enormously different velocities. Van't Hoff* found that the speed of the polymerization of cyanic acid was increased by increase in surface of the vessel and by the separation of the cyamelide on the vessel walls during the change, and decreased by the alteration of the glass surface. On the other hand, in the decomposition of arsine, the reaction only becomes regular and follows the logarithmic formula when the vessel walls are fairly well coated with arsenic.

The great influence of the vessel walls in gaseous systems makes it permissible, for the present, to suppose that the reaction occurs chiefly in the layer of gas in contact

* *Studien zur Chemischen Dynamik*, p 45.

with the vessel, and that the reaction products are then diffused into the rest of the space. This statement applies only to reactions which proceed slowly and not to explosions, but it is precisely such changes which are suitable for investigation. The irregularities just discussed throw great difficulties in the way of research, and it is a natural consequence that reactions in gaseous systems which are susceptible of quantitative treatment are rare at present.

The beginning of a chemical change is usually irregular. According to the mass law all changes should begin with their maximum velocity and the speed should continuously decrease as exhibited in the equation

$$\frac{d\,x}{d\,t} = k\,(a - x)^n$$

Bunsen and Roscoe, in their study of the combination of hydrogen and chlorine, observed that the initial velocity was small; then followed a rapid rise to a maximum, from which it slowly decreased as the mass law requires. They considered the phenomenon general and called it photo-chemical induction. The state of things at the beginning of a chemical change has not received the attention it deserves, but it is not likely that Bunsen and Roscoe were correct in this assumption, though other similar cases are known. In the case of gaseous systems, the irregularities just alluded to prevent us from drawing valid inferences, and in liquid systems the facts can be explained by catalytic action of the reaction products, and by unavoidable slight rises in temperature. Certainly the supposition that the first portion of a chemical change is not described by the mass law is too violent to be made upon the present evidence.

In liquid systems the effect of the vessel walls is of no importance, but that of the medium in which the reacting substances are dissolved is enormous. The difference is, that while in gaseous systems the influence of the vessel walls introduces an indeterminable element into the problem and prevents the quantitative treatment, the influence of the solvent is constant, and exhibits itself simply in its effect upon the velocity constant k. We owe the most

extensive researches on this subject to Menschutkin. The velocity of combination of triethylamine and ethyl iodide

$$N(C_2H_5)_3 + C_2H_5I = N(C_2H_5)_4I$$

was investigated in a great variety of solvents. The temperature was 100°. The great variation in the velocity constants is sufficiently illustrated by the fact that, taking the speed in hexane (k = ·00018) as unity, then the speed in acetone (k = ·0608) is 338, that in acetophenone (k = ·1294) is 720, in benzyl alcohol (k = ·133) 740.

Carrara has investigated the combination of ethyl sulphide with methyl iodide to diethyl-methyl-sulphine-iodide

$$(C_2H_5)_2S + CH_3I = (C_2H_5)_2CH_3SI.$$

The temperature was 100°. Taking the speed in acetone k = ·00015 as unity, that in benzyl alcohol is 40, in ethyl alcohol 100, and in methyl alcohol 620. The considerable difference between ethyl and methyl alcohol is interesting.

Little is known, as yet, regarding the connection between this influence and the other properties of the solvent. The velocity is much greater in aldehydes, esters, alcohols and oxygenated derivatives generally than it is in hydrocarbons and their halogen substitution products, but the decrease from acetophenone to acetone, for instance, shows that the speed does not always increase with the oxygen content. Nernst has pointed out* that in general the reaction velocity is greatest in those solvents which produce the greatest degree of ionisation in electrolytes and in which non-electrolytes have the smallest molecular weights. Very recently, Cohen,† acting upon a suggestion by Nernst,‡ has investigated the effect of the addition of an indifferent gas upon the velocity of decomposition of arsine. The results are particularly interesting, because they bear upon the question, whether a gaseous phase whose composition is capable of continuous variation should be regarded from the same

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* "Theoretical Chemistry," English Edition, p. 484.

† "*Zeitschrift für Phys. Chem.*," XXV, p. 483 (1898).

‡ "Theoretical Chemistry," English Edition, p. 484.

point of view as a liquid phase having the same property, that is, as a solution. The full discussion of this question lies quite outside the scope of the present paper, but the answer, so far as the study of the reaction velocity can furnish it, is negative. Cohen found that the addition of hydrogen and nitrogen in excess was without influence, and this stands in direct opposition to the behavior of liquid systems.

Catalytic action upon reaction velocity is distinct from the influence of the solvent in two respects: (1) the quantity of the active substance is small in comparison to the quantity of material changed by it, for instance, in the inversion of sugar by hydrogen ions the quantity of the latter relative to the quantity of sugar inverted may be made excessively small and the change still occur with a measurable speed; and (2) in a reversible reaction the catalyzing substance affects simply the speed with which the final state of things is attained, and is entirely without influence on the mass relations of the substances at the end of the change. This principle is easily deduced from the second law of heat. By making the opposite assumption that the catalytic substance does displace the equilibrium, we encounter a perpetuum mobile of the second kind. It is, of course, confirmed by the results of experiment. Lemoine, in his classical researches upon the decomposition of hydrogen iodide, found that the speed with which equilibrium was reached was very much increased by the presence of platinum black, but that the distribution of the substances when the equilibrium

$$2HI = I_2 + H_2$$

was reached was unaffected.

It is desirable that this fact, that the active substance in a reversible catalytic change has no effect on the final equilibrium, should become more generally known, for the opposite assumption is not infrequent in chemical literature.*

* Compare the work of Schiff on the equilibrium between the keto- and enol- forms of the esters of the ketonic acids, *Berichte*, XXXI, pp. 205, 602, 1304.

A host of facts regarding the catalytic influence of various substances on chemical changes is known, and the differential equations necessary for dealing with the data quantitatively have very recently been supplied by Ostwald.* Since the facts and the equations have not yet been brought into relation, all that we can do at present is to state the general character of the phenomena and to attend to some of the more remarkable of the facts.

Catalysis is best defined as the acceleration or retardation of a chemical process by a substance which itself remains unaltered and whose quantity bears no relation to the total amount of substance transformed. Cases of this kind of action, *e. g.*, the action of platinum in promoting the combination of hydrogen and oxygen and the decomposition of hydrogen peroxide, the inverting influence of hydrogen ions on sugar, have long been familiar. The recent discovery by Buchner of the unorganized ferment, zymase, of the yeast plant ranges the ordinary alcoholic fermentation under the head of catalytic processes. Water vapor appears to play a peculiarly important role in facilitating chemical changes catalytically. Quite a large number of qualitative facts showing this have been brought to light of late, especially by Dixon and by Baker, who have shown that some of the most familiar and energetic reactions of inorganic chemistry fail to take place, or, better, take place so slowly as to escape observation when the reacting substances are completely dry. In perfectly dry oxygen phosphorus and carbon burn only with the greatest difficulty, burning potassium is extinguished,† carbon monoxide does not burn and does not explode when electric sparks are passed, and nitric oxide mixes inertly without any production of nitrogen peroxide. Dry chlorine is without action upon copper and sodium and explodes with difficulty when mixed with an equal volume of dry hydrogen and exposed to the light of burning magnesium. Dry hydro-

* "*Lehrbuch*," Vol. II, Part II, p. 262.

† Roscoe and Schorlemmer, Vol. II, p. 228 (1898). The statement has recently been called into question.

chloric acid gas mixes with dry ammonia without the production of any ammonium chloride, and conversely perfectly dry ammonium chloride does not dissociate when vaporized. In cases like this it is best to assume, for the present, that the function of the water is to increase the velocity of the change and that in its absence the process occurs so slowly as to escape detection. It may be added that absolutely dry hydrogen sulphide is without action upon metallic salts and that dry hydrochloric acid does not appear to affect marble.

THE EFFECT OF VARIATION OF TEMPERATURE.

In all cases thus far investigated reaction velocity is enormously accelerated with rising temperature. It was found by Trevor* that the inversion of sugar proceeds four thousand times as rapidly at 100° as at 25°, and other reactions exhibit a similar behavior. Cooling to very low temperatures diminishes the reaction velocity until the change apparently does not occur at all. The most interesting work in this direction is due to Raoul Pictet.† His low temperatures were obtained by means of boiling nitrous oxide or boiling liquid air. The most remarkable result is that at temperatures in the neighborhood of — 150° substances, which ordinarily react energetically, are quite inert. Mixtures of solid sulphuric acid, with caustic soda or caustic potash can be compressed strongly at — 125° without the slightest evidence of change; if the mixture is allowed gradually to warm, then at — 80°, in the case of the soda, and at — 90° with potash there occurs a reaction, and the tube containing the mass is broken by the sudden evolution of heat. Sulphuric acid and ammonia, and hydrochloric acid and ammonia seem quite without action on each other at — 70°. Acids do not affect blue litmus, and alkalies produce no change in the color of red litmus and develop no tint in alcoholic phenolphthalein. At these temperatures the three ordinary acids do not appear to

* *Zeit. Phys. Chem.*, 10, 321 (1892).
† *Comptes Rendus*, 115, p. 814 (1892).

affect carbonates; no evolution of carbon dioxide was observed. Alcoholic barium chloride remains clear when mixed with sulphuric acid, and the same is true of silver nitrate and hydrochloric acid. Sodium thrown into hydrochloric acid swam about without any evolution of hydrogen. A later investigation of this particular reaction has shown* that the hydrochloric acid contains sodium after the experiment, and accordingly we have here simply a case of very small velocity of change and not of equilibrium. Whether we are to apply this explanation to all the changes, and consider simply that with cooling the reaction velocity becomes very small, or whether we are to consider that there may be "false equilibrium" at low temperatures without any change whatever is uncertain. Nernst† and Ostwald‡ appeal to the law of continuity and to many facts in support of the first assumption. Duhem § has developed with great mathematical ability the second. This topic belongs, however, to the subject of chemical equilibrium.

SUPPLEMENTARY.

Very recently a reaction of the fourth order—a tetramolecular reaction—has appeared.‖

The reduction of bromic acid by hydrobromic acid,

$$HBrO_3 + 5HBr = 3H_2O + 3Br_2,$$

is accurately described by the equation,

$$\frac{dx}{dt} = R(A - x)^4,$$

and the values of k calculated from the integrated form of the equation are very satisfactory. In the presence of excess of sulphuric acid the same reaction becomes bimolecular. It had been previously shown that the action of haloid acids upon their corresponding oxygen acids possessed a complex

* Dorn and Völlmer, *Wiedemann's Ann.*, 60, 848.
† "Theoret. Chem.," Eng. Edition, p. 573.
‡ "*Lehrbuch*," Vol. II, Part II, p. 287.
§ *Traité de Mécanique Chimique*, Vol. I, p. 219.
‖ Judson and Walker, *Journ. Chem. Soc.*, 73, 410 (1898).

mechanism and was probably of the fourth order, but this is the first tetramolecular reaction for which satisfactory velocity constants have been obtained.

Von Sigmond* has shown that the hydrolysis of maltose is monomolecular, and proceeds in general very similarly to the sugar inversion, except that the reaction is very much slower.

Price† has shown that the oxidation of potassium iodide by potassium persulphate,

$$2KI + K_2S_2O_8 = 2K_2SO_4 + I_2,$$

is bimolecular, and has made an interesting study of the influence of various metallic salts on the progress of the change.

The most remarkable result is that when two substances acting catalytically are present together, their influence is not necessarily additive, but that the catalytic action of one may be increased by the presence of the other. For instance, in this case, the influence of copper sulphate and iron sulphate together is more than twice as great as that calculated on the basis of a simple additive relation. So far as I am aware, this is the first instance of this kind to appear.

CENTRAL MANUAL TRAINING SCHOOL,
PHILADELPHIA, January 7, 1899.

BOOK NOTICES.

Premiers Principes d'Électricité Industrielle. Piles, accumulateurs, dynamos, transformateurs. Par Paul Janet. (Ouvrage couronné par l'Académie des Sciences.) 3ième Édition, entièrement refondue. Paris: Gauthier-Villars. 1899.

The present edition of this capital work, well known and appreciated by French readers, has been considerably enlarged and revised.

The subject of accumulators has been brought up to date, with especial reference to the application of these to electric traction, which appears to have progressed much further in France than in this country. The chapters relating to dynamos, alternators and transformers have also been considerably enlarged and rewritten to conform to the most recent practice. W.

* *Zeit. Phys. Chem.*, 37, 385 (1898).
† *Zeit. Phys. Chem.*, 37, 474 (1898).

A Treatise on Photographic Optics. By R. S. Cole, M.A., etc. Illustrated. New York: D. Van Nostrand Co. 1899. Price, $2.50.

This volume should prove a useful contribution to an important branch of applied optics, in which the literature is by no means as voluminous or satisfactory as it should be considering the universal extension of the practice of the art to which it relates.

The treatment of the subject is necessarily mathematical, but the author has endeavored to make his treatment as intelligible as possible by worked numerical examples. The chapter headings embrace the following subjects, viz.: Light, elementary theory of lenses; aberration, correction of aberration and the design of lenses; lens testing, exposure, stops and shutters; enlargement, reduction, depth of focus and halation. W.

Portland Cement, its manufacture and use. By Charles D. Jameson, M. Am. Soc. C. E., etc. New York: D. Van Nostrand Co. 1898. Price, $1.50.

This volume treats of the making, testing and using of Portland cement, and is described in the preface to be the outgrowth of a short course of lectures delivered by the author to the students of engineering in the University of Iowa.

The several chapters treat of the selection of the raw materials, their preliminary treatment, the leading types of kilns used, reduction of the clinker to powder, etc., the requirements for testing as set forth in the various standard specifications, the methods to be followed in testing and the different forms of mechanical devices employed in making the tests, the comparative value of different cements, the uses of Portland cement as a material for construction, the proper methods of manipulating it, and estimates of quantities and cost.

The volume is well illustrated and the subject is treated concisely and clearly. W.

American Newspaper Annual. (Nineteenth edition.) Philadelphia: N. W. Ayer & Son. 1899. Price, $5.

The great experience of the publishers of this annual enables them to add to the value of each succeeding volume by the introduction of new data of use to business men and others for whom the work is designed. The present edition forms an imposing volume of several thousand pages, and it is safe to say that, in point of accuracy, comprehensiveness and excellence of classification, it is all that could be reasonably desired. W.

International Railway Commission. Vol. I, Part 1. A condensed report of the transactions of the Commission and of the surveys and explorations of its engineers in Central and South America, 1891–1898. Washington. 1898.

This volume gives a general summary of the work of the Intercontinental Railway Commission, constituted for the purpose of realizing the Intercontinental Railway to connect the northern and southern portions of the American Continent. It contains an historical sketch of this ambitious project, together with a *résumé* of the legislation adopted by the Congress of the

United States, which resulted in the convocation of the International American Conference and the formation of Intercontinental Railway Commissions. It contains, also, an outline of the work accomplished by the engineers of the Commission, which may be regarded as a preliminary survey, not definitive, but presented as a contribution from the technical branch of the Commission to determine the feasibility of constructing a trans-continental trunk line.

W.

Sanitary Engineering of Buildings.—By Wm. Paul Gerhard, C.E. Vol. I (with 103 illustrations and 6 plates). New York: William T. Comstock. 1899.

This work has been prepared by the author to take the place of his "Hints on the Drainage and Sewerage of Dwellings," the third edition of which was, some months ago, exhausted.

The material of the earlier work, in revised form, constitutes the first five chapters of the present greatly enlarged work, which embraces twelve chapter headings. The author is a voluminous contributor to the technical journals, and has culled freely from these contributions for the material embraced in Chapters VI to XII; but this has been revised and expanded, and its value considerably enhanced by the introduction of new illustrations.

The present volume treats of defective plumbing and sewer gas, traps and systems of trapping, drainage and sewerage of buildings, plumbing fixtures, sewage removal and disposal, principles of scientific house drainage and sanitary plumbing, improved methods of house drainage, proper arrangement of water-closet and bath apartments, sanitation in factories and workshops, sanitary drainage of tenement houses, testing house drains and plumbing work, and simplified plumbing methods.

The arrangement of subjects appears to be excellent; and the method of treatment as thorough and reliable as we should anticipate from an engineer of the extensive professional experience of Mr. Gerhard.

A second volume, now in preparation, will treat of questions of water-supply, sanitary arrangements of suburban and country houses, sanitation of public buildings, etc., and the completed work should form a valuable reference book for the professions and trades interested in the subject. W.

La Bicyclette, sa Construction et sa Forme. Par C. Bourlet, Docteur ès Sciences, Membre du Comité technique du Touring-Club de France. Un Volume Grand in-8, 228 pp., et 264 figures. Paris: Librairie Gauthier-Villars. 1899. 4 francs, 50 c.

The author of this work, who is a distinguished contributor to the art to which it relates, has given us a very comprehensive treatise in the 225 pages comprised therein.

The volume opens with an interesting historical sketch, and which is followed in order by chapters treating of the construction and form of the machine, taking up successively the frame, the steering head, the bearings, the transmitting mechanism, speed-changing devices, wheels and tires, tricycles and "sociables," accessories.

A chapter is devoted to advice to wheelmen on the choice and care of the machine and accessories, and hygienic considerations. The concluding chapter is devoted to the theory of the bicycle. W.

The Elements of Physics. A college text-book. By Edward L. Nichols and Wm. S. Franklin. In three volumes. Vol. II, Electricity and Magnetism. New York: The Macmillan Company. 1896. Price, $1.50.

This work is well known to teachers of physics as a thoroughly trustworthy, up-to-date treatise on the subject, well arranged and adapted for its intended service. W.

Photographic Mosaics. An annual record of photographic progress. 1899. (Thirty-fifth year of publication.) New York: Edward L. Wilson; London: Dawborn & Ward.

The successive annual volumes of "Photographic Mosaics" lose nothing of their interest and value to the professional and amateur photographer. The present volume, the thirty fifth of the series, devotes 106 pages to a review of photographic progress during the previous year, which will be found convenient for reference by all who aspire to keep in touch with the current advances in the art, and the remaining 185 pages are devoted to contributions on a great variety of live subjects of interest to photographers, from well-known experts. This volume is as profusely and handsomely illustrated as usual. W.

PUBLICATIONS RECEIVED.

Acetylene Gas for Popular Lighting. Pan-American Acetylene Company, Buffalo, N. Y.

Maximum Stresses in Framed Bridges. By Wm. Cain. New York: D. Van Nostrand Co. 1897. New and revised, constituting No. 38 of the Van Nostrand Science Series. Price, 50 cents.

A Laboratory Course in Experimental Physics. By W. J. Loudon, B.A., and J. C. McLennan, B.A. New York and London: Macmillan & Co. Price, $1.90. From John Wanamaker, Philadelphia.

A Higher Industrial and Commercial Education as an Essential Condition of Our Future Material Prosperity. An address before the Society for the Promotion of Engineering Education. By J. B. Johnson, President of the Society. Delivered in Boston, Mass., August 18th, 1898. (Reprinted from the Society's Proceedings.)

Soft Coal Burning. By C. M. Higginson. (Fifth edition.) Chicago. 1898. A brief disquisition on the essential features of construction and operation of steam boilers to insure smokeless combustion with soft coals.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 21, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 21, 1899.

MR. H. R. HEVL in the chair.

Present, 201 members and visitors.

Additions to membership since last report, 40.

Mr. B. S. Lyman, Chairman of the Committee on Library, made a brief report of the present condition and needs of the library.

Mr. T. B. Kinraide, of Jamaica Plain, Mass., described a new form of induction coil of great power which he had devised, and which he has applied with remarkable success to the study of the structural forms of electrical discharges with the aid of photography. The speaker described the apparatus and exhibited it in operation. He likewise showed a large number of photographic prints of these discharges, and numerous photographic plates of large size, with the aid of the lantern. The figures thus obtained and exhibited were of extraord nary beauty, and elicited unbounded admiration.

The subject was referred to the Committee on Science and the Arts.

Mr. W. J. Clarke, of New York, followed with an experimental exhibit of his apparatus for wireless telegraphy, with which a striking and successful demonstration was made. The speaker explained the underlying principles of this branch of the art of telegraphy, and gave a brief sketch of its development.

Referred to the Committee on Science and the Arts.

Mr. John Condon, of Philadelphia, described and exhibited in operation an improved form of acetylene gas generator of his invention.

Mr. W. N. Jennings exhibited, with the aid of the lantern, some photographs showing the progress made during the past month upon the buildings of the impending exposition, and gave a brief descriptive account of them.

The meeting passed a vote of thanks to the speakers of the evening and adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, June 7, 1899.*]

The following reports were considered:

The Moskowitz System of Electric Car Lighting.—Held under rules for one month.

Protest of Mr. E. J. Moore against the Committee's report on his improvements in Moore's steam boiler.

The Committee voted to sustain the report and dismissed the protest.

Pneumatic Truck Cushion for Railway Cars.—Frederick S. Owen.

ABSTRACT.—The device consists of a corrugated steel tube, of suitable length for a car-spring, with steel heads brazed on the tube ends, one head having a plug with a valve on the point for closing the filling space in said head. The inventor's intention is to form a spring in this manner, and to use air pressure to sustain the load. (Drawings only submitted.)

The investigators are in doubt as to what such a spring would do without actual test of sufficient duration to determine the life of the metal, which they think would be short. Also, they know of no metal that could withstand the fatigue required of it by this service. [*Sub-Committee.*—Wm. Penn Evans, Chairman; J. J. De Kinder and Henry F. Colvin.]

The following reports passed second reading:

The Acid-Blast for Etching Metal Plates.—Louis Edward Levy, Philadelphia.

This report was referred back to the Sub-Committee on the representation of the applicant that a patent had just been issued to him, covering much broader ground than that which the Sub-Committee had had under consideration.

Plastic Bond for Electric Railways.—Thos. A. Edison and Harold P. Brown, New York.

ABSTRACT.—This invention is secured by U. S. letters-patent, No. 509,518, November 28, 1893, issued to Thos. A. Edison and H. P. Brown, and in substance is as follows:

The surfaces on the rails near the ends are bonded as well as the surfaces of contact of the bonding conductors—which may be either the fish-plates or appropriate copper conductors—will permit, and the contact is enhanced by the interposition between these surfaces of a plastic amalgam or alloy of mercury, with other metals, mainly copper.

This invention has been under investigation for several years, the investigators being of the opinion that the real value could only be determined by the test of time. The opinion is expressed that the success of this bond depends very largely on the care with which it is applied, but that with proper care in its installation it can be maintained in good condition, with periodical testing, at comparatively small cost. The Edward Longstreth Medal of Merit is awarded to the inventors. [*Sub-Committee.*—Geo. F. Stradling, Chairman; Thos. Spencer, Wm. C. L. Eglin, E. A. Scott.]

Internally-fired Water-tube Boiler.—Robert S. Kinney, Philadelphia.

ABSTRACT.—The invention is the subject of letters patent of the United States to applicant, No. 575,118, January 12, 1897.

The structural details of this boiler would be unintelligible without the aid of illustrations. This abstract, accordingly, will be restricted to the conclusions reached by the Committee, which are substantially as follows:

The Kinney boiler has several valuable features met with in other boilers, which may be enumerated as follows: A definite course for the feed-water, with provision for separating out the precipitable salts; a good arrangement and disposition of materials in the lining for the proper burning of soft coals; a small number of made joints, which must be broken to clean the boiler; the absence of stays.

The apparatus is credited also with the following distinctive character-

istics: Small space for a given horse-power, large evaporation per square foot of heating surface.

The investigating committee, from the results of its tests, state that in economy this apparatus is as good as any boiler used at present, and that it possesses high evaporative power for a given space at low rates of combustion. The details are well worked out, and conform to the best present practice. A certificate of merit is awarded to the inventor. [*Sub-Committee.*—H. W. Spangler, Thos. P. Conard, Wm. Penn Evans, Arthur M. Greene, Jr.]

Electric Program Clock.—Frederick Frick, Waynesboro, Pa.

ABSTRACT.—The invention is patented to applicant by letters-patent of the United States, No. 535,948, March 19, 1895, and No. 551,375, December 17, 1895.

The purpose of the invention is the production of efficient mechanism by means of which certain predetermined signals may be automatically brought into action, by electrical devices, at times and places desired. This is useful, especially in schools, colleges and institutions, in announcing time for studies, recreation, rising, retiring, etc., and for analogous service in manufacturing and business establishments, where regularity is a necessity, according to a prearranged program.

The mechanism consists of a clock or timepiece of good construction for keeping correct time, and of a spring motor operating to revolve a disc of metal a portion of a turn at short intervals of time, the disc having a series of perforations arranged in concentric circles and in radial rows with pins fitting in certain spaces of the same, which make contact through a spring contact-piece, forming an electric current and ringing a bell or bells.

The mechanical details could not be explained without illustrations.

The report finds the meritorious features of this apparatus to consist: (1) in the relieving of the time-keeping mechanism of almost all labor, the lifting of the lever and the operation of the starting spring being all that is required of it; (2) the substitution of a flat disc of metal to carry the pins of the program-contacts, which are seen and inserted with great facility; and (3) the improved form of the calendar switch in which the pins are readily changed, and which are not in any electric circuit. These, the investigators believe, constitute an advance in the art.

Also, the investigators report the satisfactory operation of these clocks in actual service, one of them having been under the personal observation of one of the members of the Committee for four months, and to confirmatory evidence from a number of those having the apparatus in use. It relieves the head of the school or institution of annoyance in not having signals given promptly, with all the attendant confusion resulting from the want of a reliable signalling device.

The inventor is given the Edward Longstreth Medal of Merit in recognition of the merits of his program clock. [*Sub-Committee.*—J. Logan Fitts, Louis Breitinger, Hugo Bilgram, Wm. T. Lewis.]

The stated meeting of June 7th is the last prior to the summer recess. The Committee stands adjourned until the stated meeting of September 6th. W.